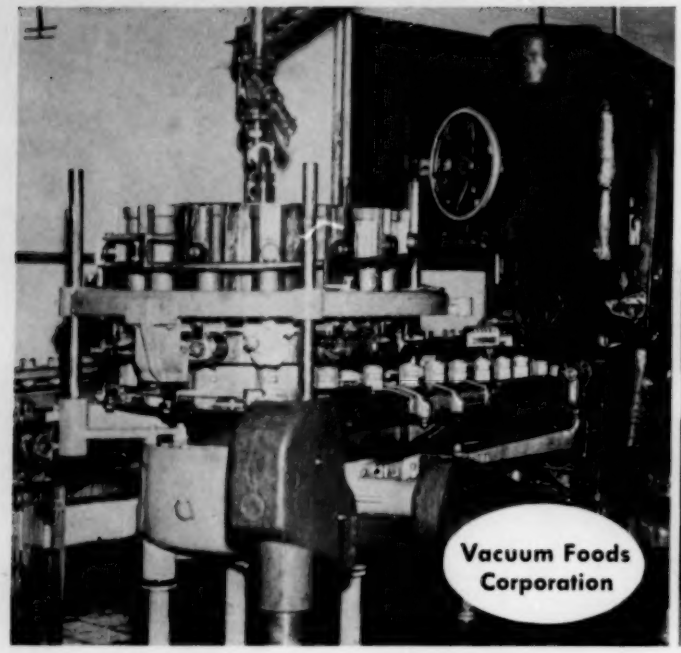
Food Eng. Library
TX
341
F69
v.4
no.2

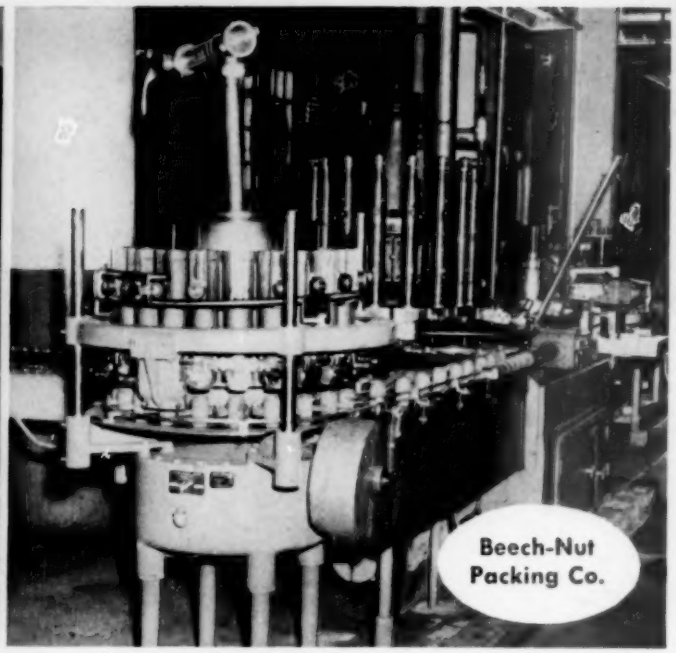
FOOD TECHNOLOGY

PUBLISHED BY THE INSTITUTE OF FOOD TECHNOLOGISTS

Volume IV, Number 2
February, 1950

UNIVERSITY OF MICHIGAN LIBRARIES



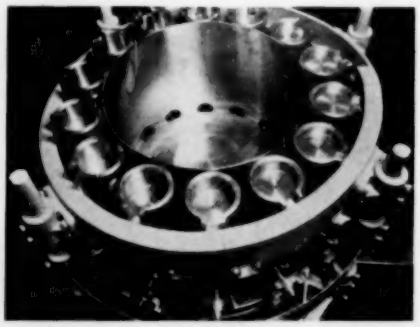


Dependable and accurate at high speeds . . .

Pfaudler Piston Fillers

You can do more filling jobs with a Pfaudler Piston Filler than any other machine available!

Proved performance. Here is a machine that is used by such companies as Vacuum Foods Corporation for filling frozen orange juice; Beech-Nut Packing Company for filling baby foods; Republic Foods for filling potted meats—to mention a few products. It handles everything from thin liquids to semi-solids and is easily adapted to changing requirements. With a single machine you get maximum operating flexibility.



Outstanding capacity. Pfaudler Piston Fillers are available in two sizes—14 and 21 stations. The smaller machine handles up to 350 No. 2 containers per minute; the larger, up to 575 per minute. Standard minimum openings 1½" diameter. Special nozzles are available for use on openings as small as ¾" diameter.

Cost-cutting features. High speed accurate filling is achieved through precision-timed two port valves. On the upward stroke of each piston, one port of valve opens and feeds product into piston cylinder. On downstroke of piston, opening port closes and discharge port opens, allowing product to fill container. *If there is no container under valve, valve ports automatically reverse, forcing product back into filler bowl.* Waste is eliminated. Adjustment of valves for different size containers is done in one simple operation, saving time. Get the complete story. Ask for Bulletin 848.

Pfaudler

THE PFAUDLER CO., Rochester 3, N. Y. Branch Offices: 330 West 42nd St., New York 18, N. Y.; 111 W. Washington St., Chicago 2, Ill.; 1325 Howard St., San Francisco 3, Calif.; 818 Olive St., St. Louis 1, Mo.; 2970 West Grand Blvd., Detroit 2, Mich.; 1318 1st Nat'l Bank Bldg., Cincinnati 2, O.; 1041 Commercial Trs. Bldg., Philadelphia 2, Pa.; 751 Little Bldg., Boston 16, Mass.; 334 Chattanooga Bank Bldg., Chattanooga, Tenn.; P. O. Box 4066, Dallas, Texas; Taylor St., Elyria, Ohio; 1346 Connecticut Ave. N. W., Washington 6, D. C.; Enamelled Metal Products Corp., Ltd., Artillery House, Artillery Row, London, S. W. 1, England.

THE PFAUDLER CO., ROCHESTER 3, NEW YORK

Engineers and Fabricators of Food Processing Equipment

GLASS-LINED STEEL
Hastelloy—Aluminum
Tantalum—Carbon Steel
Solid or Clad Stainless Steel
Nickel, Inconel, Monel

Food Technology in Australia

There has recently come to our desk from "down under" the latest addition to that group of journals which is devoted to the technology of foods. Published by the Council of Australian Food Technology Associations and representing and coordinating all the State Food Technology Associations, of which there are four, it bears the title *Food Technology in Australia.* Its aims are to promote the scientific and technical aspects of the food manufacturing industries in Australia and, as we learn from the lead editorial of its second issue, to make this Journal a medium of disseminating knowledge of where to find information of value to the food processing industries there. To that end, it is stated, limited space will be given to technical articles of a general nature until such time as a substantial literature on Australian food technology is available. In the meantime it is intended to concentrate more on directing attention to published matter from all over the world by resorting to abstract, comment and review of the literature, for the number of individuals and institutions in Australia engaged in food technology research and development and prepared to publish their results is still small.

That an auspicious start has been made on the program as outlined above is reflected in the material which has been published in the issues available for review at this writing. Dr. C. S. Miner's Perkin medal address of 1948 entitled "Science versus Starvation" finds, as it deserves, top position in the first issue. This is followed by excerpts of an address by Professor Z. I. Kertesz to the Food Technology Association of New South Wales on, "Some recent technical developments in food processing research in the U. S. A." This is followed by a discussion of the activities and research programs, past and present, of the British Food Manufacturing Industries Research Association. Back to the "States" again the editor next briefly turned his attention to a report on the symposium on ion exchange presented before the Division of Water, Sewage, and Sanitation Chemistry at Chicago in 1948. A summary of the most changes in "Methods of Analysis" of the A. O. A. C., and book reviews, plus a few items of minor interest, complete the first issue.

In the second issue the reader is informed under the general title of Overseas Notes—this is promised to be a regular feature—of modern equipment for concentrating liquid foods. The new-food dinner which was given as a prelude to the 14th Annual Meeting of the National Farm Chemurgic Council in Memphis last Spring next rates a place under the caption "Food Technology with a Vengeance." The promised abstracts from the literature follow in larger number than before. A full page is next devoted to an informative review of Britain's newly launched "Food Science Abstracts." A new feature, "Educational Activities" makes its appearance here.

Food Technology welcomes to the field this new comer from Australia, and wishes it every success in the program which it has set up for itself. Good luck.

H. A. Schuette.

TASTE TEST PANELS

Abstract by Martin Heerdt.

Anonymous Article published in *National Provisioner* **121**, No. 16, 10, 11, 26 (October 15, 1949).

Two general types of observers are used on taste test panels. One type is defined as "consumer" and may include anyone with the exception of persons who are technically familiar with the product under investigation. The other general type is called the "trained panel." Individuals on these panels have been selected because of their superior skill.

Panel members are selected, first, on their ability to detect typical differences between samples, and, second, on their ability to duplicate performance in flavor evaluation tests. From 50 to 80 persons are screened using several pairs of samples which have obvious differences. The superior ones from this large group are tested intensively on successively fine degrees of difference until it is possible to determine their order of skill. These panel candidates also evaluate a number of samples of varying quality on a rating scale, then reevaluate the same samples later without knowledge of previous performance. The degree of correlation between the two performances is the measure of their skill. Out of the original 50 to 80 candidates only 20 to 25 persons are selected for the panel on the basis of their performance in both tests.

Trained panels are required for difference tests which are used to evaluate any operation that might conceivably alter the sensory properties of a food. These groups consider products analytically to determine their more important taste and odor properties. Such tests are non-controlled and non-precise, but they can give valuable leads to research and development work. The panels also evaluate samples by the use of rating scale tests in which they give opinions as to excellence and thereby predict consumer acceptance fairly well.

"Consumer" groups consisting of 30 to 60 persons are used only for tests which ask a question about individual preference for, or attitude toward, a food as distinguished from the type of test designed for trained panels, which asks for a judgment. Tests suitable for use with such groups include: 1) paired comparisons, 2) rank arrangement of a series of samples in order of preference, and 3) observers response to samples presented singly, expressed in one of nine degrees ranging from "dislike extremely" to "like extremely." The paired-comparison and rank arrangement tests give only comparative ratings while the attitude scale gives absolute values that correlate with basic acceptance. However, the results of the latter are not as precise as those of the other two tests.

The trained panel methods are used in development work on food items and military rations. "Consumer" groups are used to assess progress during the development and to pass on the final product.

Commercial Fisheries Abstracts, January 1950.

The Significance of Chronic Toxicity Studies[a]

FLOYD DEEDS

(From the Pharmacology Laboratory, Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, U. S. Department of Agriculture, Albany 6, California)

(Received for publication, July 25, 1949)

(REVIEW PAPER)

Pesticidal compounds may produce acute or chronic poisoning. The symptoms and mode of action in these two forms of toxicity are not necessarily the same and are frequently different. The data from acute toxicity studies may therefore be of little value in predicting the dosage, symptoms, mechanism of action or proper antidotal measures in chronic poisoning.

In 1931 a pharmacology laboratory was established in the Food Research Division of the former Bureau of Chemistry and Soils. One of the purposes of the laboratory was the determination of the acute and chronic toxicities of new organic pesticides being developed to replace or supplement lead, arsenic, and fluorine compounds. There have been changes in the organization of that Bureau, which is now known as the Bureau of Agricultural and Industrial Chemistry. The Food Research Division no longer exists, but four regional research laboratories have been created. These laboratories are concerned with the utilization of farm crops, with emphasis on surpluses and wastes. Their investigations have in turn created new problems requiring pharmacological study. Among these problems are: determination of the presence or absence of toxic factors in byproduct feed materials, the toxicity and best modes of administration of antibiotics produced from or with the aid of agricultural products, the toxicity of antioxidants, the toxicity of products of fermentation, and the toxicity and pharmacological properties of substances having potential medicinal value.

Our experience in toxicological studies on a wide variety of substances has emphasized the need for an understanding of the nature of chronic toxicity and its differentiation from acute toxicity. The need for this understanding applies to all types of compounds, whether they are organic or inorganic, and whether they are compounds used in food processing, pesticides, or potential medicinal agents.

Ten years ago I had occasion to discuss this differentiation of acute and chronic toxicity before the Sixth Pacific Science Congress held here in the Bay Area *(1)*. At that time the differences in the symptoms and mechanism of action in acute and chronic fluorine poisoning were used to illustrate the points discussed. Today the significance of the differentiation can be discussed more effectively in terms of data obtained by us and other investigators on compounds studied since that time.

Ten years ago I stated: "The inherent differences in acute and chronic poisoning are largely responsible for the lack of appreciation, especially among the laity, of the public health hazards of chronic poisoning in general. The symptoms of acute poisoning are often well known and the correlation of the fatal end result with the causative agent is frequently relatively simple. Quite the reverse may be true in chronic poisoning. For many agents the nature of chronic poisoning is unknown, and there is a lack of the dramatic features which frequently characterize acute poisoning.

"We should have a clear idea of what is meant by chronic toxicity, or cumulative poisoning as it is frequently called. There seems to be an idea prevalent among the laity and present even in the minds of some investigators that chronic toxicity, that is, toxicity due to repeated intake of a substance over a long period of time, is associated with a storage in one or more organs of the body, and that when the amount of stored substance reaches a certain magnitude symptoms of toxicity ensue. Even if this type of mechanism could be shown to be true for certain substances, it obviously represents a restricted definition of chronic toxicity and a rather naive point of view. Such a definition would imply that if the amount of a substance taken in equaled the amount excreted in the urine, feces, expired air, or perspiration, or any combination of these avenues of elimination, there would be no storage and, by definition, no toxicity. It is evident that the definition must be broadened so as to include the possibility of cumulative injury to tissue cells by virtue of a chronic exposure to a streaming of the agent through the body. Such a definition helps us to appreciate the possibilities of poisoning when no storage takes place and elimination is quantitative. It also enables us to visualize the possibility that storage within some body structure may be as effective a method of removal as excretion, and that if the streaming of a potentially toxic agent through the tissues from the point of entrance to the storage depot involves a low enough concentration of the agent, toxicity may not supervene. It also becomes possible to understand how an agent, which was stored without producing demonstrable symptoms of toxicity, may subsequently be released from storage at a rate giving rise to a concentration in the tissues high enough to produce symptoms. The important inference to be drawn is that chronic poisoning is the result of cumulative tissue injury produced by a continued streaming of a toxic agent in adequate concentration through the tissues over a period of time.

"It is not surprising that the symptoms of acute and chronic poisoning by a given agent may be quite different. A single illustration will suffice. The symptoms of acute poisoning by sodium fluoride are pain, dysphagia, nausea, vomiting, nephrosis, decreased coagulability of the blood, and shock. These symptoms are due chiefly to a corrosive action and to calcium deprivation. Administration of calcium is a fairly good antidotal measure. On the other hand the symptoms of chronic poisoning by sodium fluoride are impaired nutrition, anemia, deposition of fluoride in the bones and teeth, rendering the osseous tissue more brittle,

[a] Presented before the Ninth Annual I. F. T. Convention, San Francisco, Calif., July 14, 1949.

and causing a mottling of the clear pearly enamel of the teeth with dull opaque white areas. These chronic manifestations are traceable to the action of the fluoride ion as a general protoplasmic poison, an inhibitory action on enzymes, and the deposition in the osseous structures of a fluorine, calcium, and phosphorus complex analogous to the mineral apatite.

"In general, chronic poisoning is characterized by the prolonged action of a substance, usually in minute quantities, results in an accumulation of injuries detrimental to health, and resembles the symptoms of chronic disease. Such poisoning may predispose to intercurrent disease, and may eventually produce death. The causative agent is not necessarily demonstrable chemically in the body fluids or tissues, but functional injuries may exist."

Of the many compounds we have investigated 2-acetaminofluorene *(2, 3, 4, 5, 6)* serves well to illustrate the difference between acute and chronic toxicity and the serious consequences which may eventually appear at a time when the causative agent is no longer present in the tissues and body fluids. The oral administration of single large doses of 2-acetaminofluorene never produced any detectable signs of toxicity in experimental animals. However, when rats were fed a diet containing as little as 0.004 percent, or 40 parts of 2-acetaminofluorene per million parts of diet, they developed cancer. When rats were fed a diet containing 0.125 percent, or 1250 parts per million of 2-acetaminofluorene for a period of 25 days, and subsequently placed on a normal diet, no symptoms of toxicity appeared during the 25-day period nor during a number of months thereafter. However, after these rats were maintained on the normal diet for about 525 days, cancer was present in many of the animals. Since 2-acetaminofluorene is rapidly excreted, it is evident that passage of the compound through the animal tissues for 25 days must have initiated changes which eventually became manifest as cancer. This is a striking example of serious tissue damage becoming manifest at a time when the causative agent is no longer present.

By way of contrast let us consider cyanide and nicotine, both of which are toxic acutely but show negligible chronic toxicity. Acutely, cyanide is extremely toxic, and the mechanism of action involves poisoning of the respiratory enzymes and an interference with intracellular oxidation. In sharp contrast to this is the fact that subacute or practically symptomless doses of cyanide can be administered at frequent intervals, almost indefinitely. This lack of symptoms of chronic poisoning is due to the fact that the body converts cyanide rapidly to the non-toxic thiocyanate.

Acutely nicotine is one of the most rapidly fatal of all poisons, acting with a swiftness comparable to that of hydrocyanic acid. A drop of nicotine placed on the tongue of a rabbit rapidly produces convulsions and death by paralysis of the respiratory center. However, when attempts were made to induce chronic nicotine poisoning *(7)* by incorporating nicotine in the diet of albino rats, all the symptoms noted could be duplicated in control rats by limiting the food intake to levels comparable to those of animals on diets containing nicotine. This was true in spite of the fact that rats on diets containing 0.006 percent nicotine and growing as well as the controls, received daily 4 milligrams of nicotine per kilogram of body weight. This rate corresponds to a daily intake of 280 milligrams of nicotine for a man weighing 70 kilograms. On the highest dosage level used in these rat experiments, the daily nicotine intake was 120 milligrams per kilogram of body weight despite the lowered food intake. When nicotine-fed rats were returned to a normal diet a normal rate of growth was resumed. Surely these results are in striking contrast to the well-known acute toxicity of nicotine.

In Table 1 the typical symptoms of acute and chronic toxicity of a number of substances are summarized for comparison to emphasize the difference between these two forms of poisoning.

Instances of the lack of a relationship of the phenomena of acute toxicity to those of chronic intoxication could be multiplied. In fact the lack of relationship could be established by reference to the various vitamins and hormones. A constant streaming of these substances through the tissues and body fluids is essential to life, but they can produce serious symptoms of acute toxicity when large single doses are administered.

TABLE 1

Element or Compound	Oral Toxicity	
	Acute	Chronic
Lead	Rather rare. Usually due to acetate or subacetate. Abdominal pain and vomiting. Severe colic may occur in several days.	Digestive disturbances. Lead line, anemia, pallor, loss of weight and strength. Neuritis and muscular paralysis.
Arsenic	Violent inflammation of digestive tract. Marked relaxation of capillaries of intestines. Watery diarrhea.	Degenerative change of capillary endothelium and cells of liver, kidney, heart-muscle, etc. Muscular atrophy, polyneuritis. Destructive action on bone marrow and blood formation.
Fluorine	Corrosive action. Gastric pains, nausea, vomiting, decreased coagulability of blood, shock.	Impaired nutrition, anemia, brittle bones, mottled teeth.
Cadmium	Nausea, vomiting, kidney damage.	Anemia, enlarged heart, mottled teeth.
Nicotine	Paralysis of all ganglia. Convulsions and death by paralysis of respiratory center.	Digestive disturbances and loss of appetite.
Cyanide	Poisoning of respiratory enzymes and stoppage of intracellular respiration.	Low toxicity due to conversion to thiocyanate, although cachexia and neuritis have been reported.
2-Acetaminofluorene	No acute toxicity has been demonstrated.	Produces cancer.
Thiourea	Pulmonary edema.	Produces hypothyroidism. Reduced metabolic rate, and increased fat deposition.
DDT	Tremors, convulsions and death.	Liver damage.

The conclusion is forced upon us that it is dangerous to draw inferences from acute toxicity data as to dosages, symptoms or mechanism of action in chronic poisoning. This fact is unfortunate, for it complicates and prolongs seriously the general problem of evolving effective, yet safe, substitutes for the undesirable pesticides in use at the present time. Development of new organic compounds and determination of their pesticidal value, followed by studies on chronic toxicity to permit evaluation of their safety or harmfulness in spray residue, is a logical program, but the time required in the last step slows down the tempo of the whole program.

Because of the development of many new pesticides and because of the desirability of speeding up the pharmacological evaluation of the new compounds, there is a temptation to resort to "screening tests." A "screening test" is a relatively quick, short-cut method of classifying compounds as slightly toxic, moderately toxic, or highly toxic. Such a test involves a relatively small number of experimental animals spread over a relatively large range of dosages, and no claim for highly accurate data is made. A primary objective of a "screening test" is the selection of compounds which merit a more detailed and accurate study, compounds which possess pesticidal value but low toxicity to experimental animals. By their very nature "screening tests" give data on acute or subacute toxicity, and are not necessarily of much value for the evaluation of chronic toxicity.

There is no short-cut method for the determination of the chronic toxicity of a proposed new pesticide. Since a major question raised concerns the public-health hazard that may be associated with the eating of spray residues, feeding of the compound to experimental animals over protracted periods is the basic procedure to be followed. Observations must be made on rate of growth, fertility, food and water intake of the experimental animals, and their general appearance and behavior. Upon completion of the feeding period, all animals should be autopsied and observed for gross changes in the various organs. Stained sections of the organs must be examined by a competent pathologist for histopathological changes indicative of injurious effects.

This general basic plan for the investigation of chronic toxicity may fail to reveal certain toxic reactions for a specific compound. No general plan of study can be formulated which will guarantee the discovery of special or peculiar toxic properties of a specific compound. Instead reliance must be placed upon the experience, imagination, and ingenuity of the investigator, as exemplified in studies on dichlor-diphenyl-trichlorethane (DDT).

The publicity given to DDT during and subsequent to the war has familiarized most of us with the high acute toxicity of the compound to many insects and its low toxicity to man when properly used. DDT has fallen short of being the ideal insecticide not only because of the development of a tolerance for the compound by insects, but also because of its chronic toxicity to mammals and its acute toxicity elicited under certain conditions.

The outstanding characteristics of severe acute poisoning by DDT are tremors, convulsion, and death. The most prominent characteristic of chronic poisoning by DDT is liver damage, reported by Fitzhugh and Nelson *(8)*. The liver damage resulted from the daily ingestion of amounts of DDT too small to elicit the tremors characteristic of acute poisoning. Here again, in the case of DDT, striking differences are seen between acute and chronic toxicity.

It was pointed out earlier in this paper that toxicity symptoms may not occur when the streaming of a potentially toxic agent through the tissues from the point of entrance to the storage depot involves a low enough concentration of the agent. However, the agent stored without producing recognizable toxic symptoms may be released subsequently from storage at a rate giving rise to a concentration in the tissues high enough to produce symptoms. This is exactly the situation described for DDT by Fitzhugh *(9)*. DDT is stored in the body fat and the daily ingestion of amounts producing no signs of toxicity may result in the storage in the fat depots of amounts of DDT equivalent to several acute intravenous lethal doses. The withdrawal of food or the production of an infection in such DDT-treated animals resulted in characteristic DDT tremors. The DDT was supposedly liberated at a sufficient rate or in adequate concentration by the metabolism of the fat depots to produce the symptoms characteristic of DDT poisoning.

In summary, acute and chronic toxicity must be differentiated. An understanding of the nature of chronic toxicity permits us to understand that: (a) there is no short-cut method to the determination of chronic toxicity data; (b) acute toxicity data frequently bear no relationship to the facts of chronic toxicity; and (c) the accumulation of injuries detrimental to health in chronic poisoning may resemble chronic disease or predispose to intercurrent disease.

LITERATURE CITED

1. DeEds, F. Insecticides, pest control agents, and spray residues in relation to the public health: Fluorine toxicity. *Proc.* Sixth Pacific Science Congress, Vol. VI, 177 (1939).
2. Wilson, R. H., DeEds, F., and Cox, A. J., Jr. The toxicity and carcinogenic activity of 2-acetaminofluorene. *Cancer Research*, **1**, 595 (1941).
3. Wilson, R. H., DeEds, F., and Cox, A. J., Jr. The carcinogenic activity of 2-acetaminofluorene. II. Effects of concentration and duration of exposures. *Cancer Research*, **7**, 444 (1947).
4. Wilson, R. H., DeEds, F., and Cox, A. J., Jr. The carcinogenic activity of 2-acetaminofluorene. III. Manner of administration, age of animals, and type of diet. *Cancer Research*, **7**, 450 (1947).
5. Wilson, R. H., DeEds, F., and Cox, A. J., Jr. The carcinogenic activity of 2-acetaminofluorene. IV. Action of related compounds. *Cancer Research*, **7**, 453 (1947).
6. Cox, A. J., Jr., Wilson, R. H., and DeEds, F. The carcinogenic activity of 2-acetaminofluorene. V. Characteristics of lesions in albino rats. *Cancer Research*, **7**, 647 (1947).
7. Wilson, R. H., and DeEds, F. Chronic nicotine toxicity. I. Feeding of nicotine sulfate, tannate, and bentonite. *J. Ind. Hygiene and Toxicology*, **18**, 553 (1936).
8. Fitzhugh, O. G., and Nelson, A. A. The chronic oral toxicity of DDT (2, 2-Bis p-chlorophenyl-1, 1, 1-trichloroethane). *J. Pharm. Exptl. Ther.*, **89**, 18 (1947).
9. Fitzhugh, O. G. Use of DDT insecticides on food products. *Ind. Eng. Chem.*, **40**, 704 (1948).

Laboratory Studies on Factors Affecting Leaching Losses During the Processing of Apples[a]

ANN M. MYLNE AND C. G. SEEGMILLER
Western Regional Research Laboratory,[b] Albany, California

Received for publication, August 1, 1949

Apple slices immersed in distilled water, and in solutions of sodium chloride, calcium chloride and sulfur dioxide for varying times showed leaching losses ranging from a minimum of about 5 percent of the sugar present in the apple (one minute leach), to a maximum of about 50 percent (24 hour leach). Within practical limits, the effects due to kind of salt used, agitation of the immersion medium, and variety and maturity of apples are of secondary importance.

In processing for canning, freezing or drying, whole peeled apples and apple slices are commonly immersed in aqueous solutions of salt, calcium chloride, and sulfur dioxide. Moreover, the processing of apples for dehydrofreezing *(5)* involves, as one possible method of enzyme inactivation, the dipping of apple slices in solutions of sulfur dioxide. Hence, a series of laboratory experiments has been carried out to obtain data which could be used to estimate the amount of leaching which might be expected during such operations. Since roughly 70 percent of the total solids present in the edible portion of raw apple is sugar, the leaching experiments were based on determinations of total sugar in the leach solutions after various immersion times.

Leaching experiments were conducted on three varieties: Gravenstein apples obtained from the Sebastopol area of Sonoma County, California; Winesaps from Yakima, Washington; and Newtown Pippins from the Watsonville area of California. Apples were held in 33° F. (0.56° C.) storage until used.

Analytical Methods and Procedure

Chemical analyses of the apples, for the purpose of characterizing the raw material, preceded the leaching experiments by a few days. Each variety of apple was analyzed in duplicate for total solids, alcohol-insoluble solids, protopectin, soluble pectin, starch, free titratable acidity, and reducing and total sugars. Representative samples of apple slices were thoroughly disintegrated with equal weights of cold ethanol, and suitable aliquots of the resultant slurry were used for the analyses. Total solids were determined by a modification of the vacuum-oven method developed by Makower, Chastain, and Nielsen *(6)* for dehydrated vegetables, with an oven temperature of 50° C. (122° F.) and a 24-hour drying period. Pectic substances, as calcium pectate, were determined by a modification of the Carré-Haynes method *(1)*, using the alcohol–insoluble solids fraction as the starting material. Starch was determined by the method of Hassid, McCready, and Rosenfels *(4)*. Free titratable acidity was determined by titrating with alkali, with a commercial glass electrode pH meter. Reducing and total sugars were determined by a modification of the cerate oxidimetric method *(3)*. Results of the chemical analyses are summarized in Table 1.

Procedure

Sized (175-225 g. each) apples, after reaching room temperature, were peeled, cored, and leached whole or as radial[c] or transverse[d] slices (fourteenths). Weighed samples of approximately one pound of radial or transverse slices, held in stainless-steel mesh baskets (diam. 5 inches, height 9.5 inches) were agitated (by raising the baskets out of the solutions and lowering them again every ten seconds), or soaked in various solutions at room temperature in one-gallon Pyrex glass cylindrical jars (diam. 5.8 inches, height 12 inches). Four-pound samples of whole peeled apples in baskets (diam. 7.8 inches, height 7.5 inches) were submerged in two-gallon jars (diam. 8.5 inches, height 9.8 inches).

Solutions used included those of sodium chloride, calcium chloride, and sulfur dioxide; two sets of experiments involved the use of distilled water. Three concentrations of salt, low, medium and high, were used for both sodium chloride (0.7, 1.8 and 3.6 percent), and for calcium chloride (1.0, 2.7 and 4.6 percent). The sodium and calcium chloride solutions of medium concentration were prepared so as to have estimated osmotic pressures of 13 atmospheres, since such solutions are isotonic with apple cell sap according to Hackney *(2)*. The solutions

[a] Presented before the Ninth Annual I. F. T. Meeting, San Francisco, California, July 12, 1949.

[b] Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, United States Department of Agriculture.

[c] Radial slice: a wedge cut parallel to the principal axis of the apple, i.e., from stem end to calyx end. This is the slice commonly used for pie stock. Each apple was divided symmetrically into 14 equal sections.

[d] Transverse slice: a slice cut perpendicular to the principal axis of the apple. Seven flat ring-shaped slices 0.25-inch thick were cut from the apple, and then divided symmetrically into 14 half-rings.

TABLE 1

Analytical Data on Raw Gravenstein, Winesap and Pippin Apples[e]

Variety	Sugar as glucose		Free titratable acidity (Calc'd as malic) %	Total solids %	Alcohol insoluble solids %	Pectic substances[f]			Starch %
	Total %	Reducing %				Protopectin %	Soluble pectin %	Total pectin %	
Gravenstein	10.5	8.6	0.51	14.0	2.17	0.30	0.20	0.51	0.12
Winesap	11.6	9.4	0.49	17.7	1.77	0.35	0.04	0.39	0.01
Newtown Pippin	13.1	8.9	0.44	17.0	1.92	0.42	0.12	0.53	0.01

[e] The analytical values represent the means of duplicate determinations. [f] As calcium pectate.

of low and high concentration were prepared to test the effect of hypotonic and hypertonic solutions and correspond to estimated osmotic pressures of 5 and 25 atmospheres, respectively. The sulfurous acid solution contained 0.4 percent sulfur dioxide (estimated osmotic pressure, 2 atm.). The initial weight of each of the salt solutions and of distilled water was 1500 g.; in the case of the sulfurous acid solution, 1800 g. were used.

For the majority of experiments, the time of exposure ranged from 1 minute to 2 hours; in addition, the leaching of Winesap and Pippin radial slices resulting from a 24-hour soaking period in 1.8 percent sodium chloride solution was determined; in these latter experiments microbiological examinations established the absence of appreciable yeast, mold, or bacterial contamination.

Samples of the solutions were removed periodically for total sugar determinations *(3)*, and leaching losses were calculated as percent of total sugar present in the apples before leaching. The sugar in the apples was determined on an aliquot of an apple-alcohol slurry prepared from a representative sample of slices from the same lot of apples used in the leaching experiments.

TABLE 2

Gravenstein Radial Sections and Transverse Half-Slices

Solution	Initial concentration	Treatment	Contact time	Leaching losses	
				Radial sections	Transverse half-slices
	%		min.	%	%
NaCl	0.7	Soaked	5	6.5	9.2
			10	7.6	10.8
			30	8.8	13.2
			120	11.2	21.0
NaCl	1.8	Soaked	5	5.8	8.0
			10	6.8	9.4
			30	7.6	10.0
			120	8.1	10.9
NaCl	3.6	Soaked	5	6.0	6.7
			10	7.0	8.0
			30	7.8	8.9
			120	8.3	10.2
$CaCl_2$	1.0	Soaked	5	6.3	6.6
			10	7.3	8.0
			30	8.0	9.4
			120	9.3	13.0
$CaCl_2$	2.7	Soaked	5	5.8	7.0
			10	7.0	8.5
			30	7.8	9.6
			120	8.5	10.5
$CaCl_2$	4.6	Soaked	5	5.7	6.7
			10	6.9	8.4
			30	7.6	9.7
			120	8.5	11.2
NaCl	0.7	Agitated	2	5.9	7.9
			6	7.7	10.5
			10	8.0	11.4
			30	8.9	13.3
NaCl	1.8	Agitated	2	6.3	6.8
			6	8.1	8.6
			10	8.4	9.2
			30	8.9	9.6
NaCl	3.6	Agitated	2	5.7	7.0
			6	7.7	9.3
			10	8.2	10.0
			30	9.1	11.0
$CaCl_2$	1.0	Agitated	1	4.9	6.2
			5	7.1	9.7
			10	7.7	10.7
			30	8.3	12.1
$CaCl_2$	2.7	Agitated	1	4.8	6.6
			5	7.0	9.9
			10	7.5	10.5
			30	7.9	11.1
$CaCl_2$	4.6	Agitated	1	5.1	6.0
			5	7.3	9.5
			10	8.0	10.5
			30	8.6	11.6
SO_2	0.4	Agitated	1	....	7.2
			6	11.9	14.1
			16	16.1	19.4
Dist. H_2O		Agitated	1	5.1	6.8
			6	8.7	13.4
			16	11.9	19.1
			46	18.0	26.8

Results

Extensive experiments were carried out on *Gravenstein radial slices*, and the losses of sugars from these samples were quite significant in all cases, ranging from about 5 to 18 percent of the total sugar originally present in the apples. The results are shown in Table 2 and in Figures 1 and 2. Initial rates of loss of sugars were somewhat accelerated by agitation, but when the samples had been immersed as long as ten minutes, differences in percentages of sugars leached, under the two conditions (soaked and agitated), were small. Losses of sugars from slices immersed in sodium chloride solutions were very similar to the losses in corresponding (same osmotic pressure) solutions of calcium chloride.

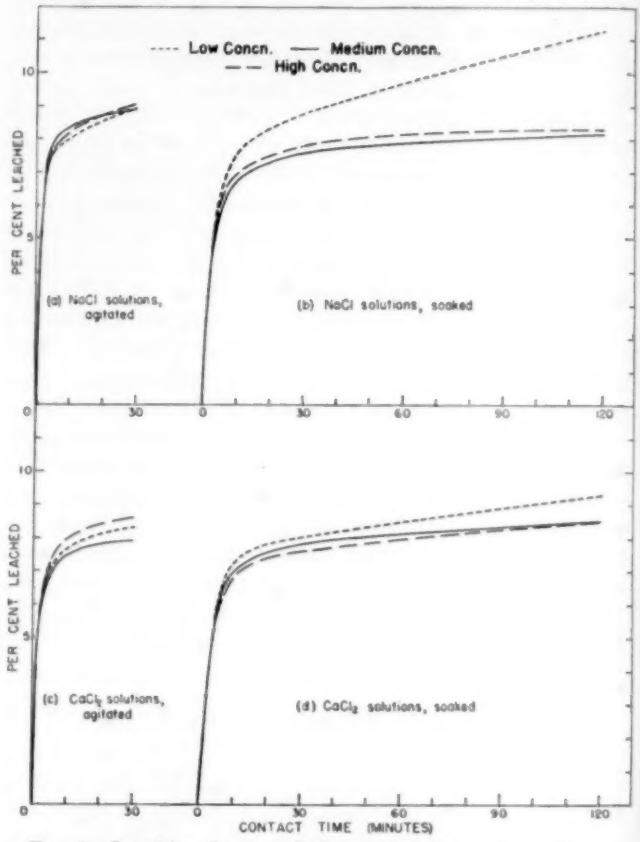


FIG. 1. Leaching Losses—Effect of Concentration. Gravenstein Radial Sections in Salt Solutions of Low, Medium, and High Concentration.

Concentration of sodium chloride (or of calcium chloride), in the range investigated, had little effect on losses from both agitated and soaked samples, except for the low-concentration sodium chloride solution which, during 120 minutes, caused a leaching loss about one-third greater than that for the solutions of medium and high concentrations.

Losses of about 5 percent of the total sugar were found in all agitated samples immersed for one minute. Such losses are probably from cut and bruised cells and are close to the minimal losses one could expect. Since a sharp-edged slicer would injure fewer cells than a blunt or dull instrument, such results are dependent

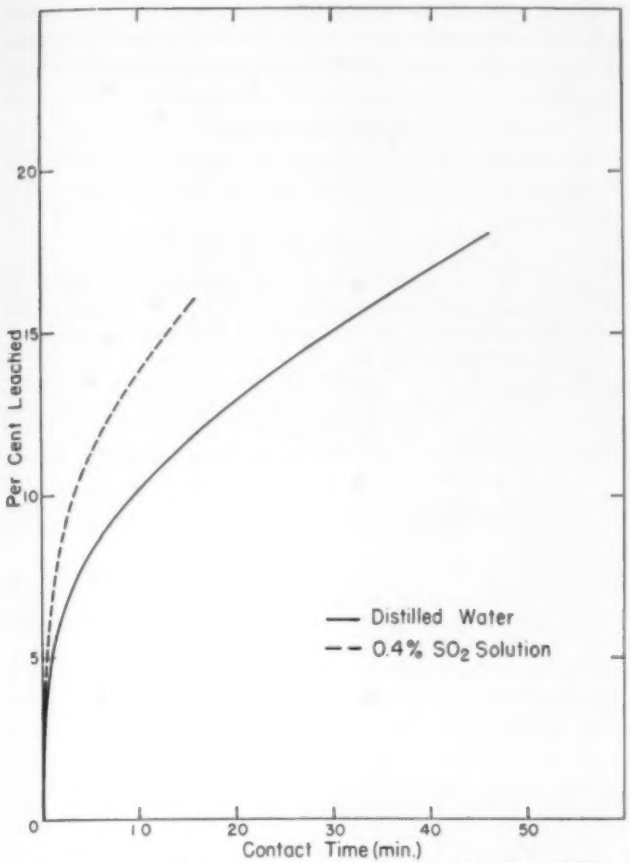


FIG. 2. Leaching Losses in Sulfurous Acid and in Distilled Water. Gravenstein Radial Sections.

upon the particular slicer used and are primarily comparative in nature.

Leaching losses from the radial slices held in either sodium chloride or calcium chloride solutions showed a tendency to level off after 10 minutes at around 7 percent (7 percent for soaked, 8 percent for agitated) and, after 30 minutes, the rates of leaching were very slow for solutions of medium and high concentration.

Rates of leaching of sugars from the radial slices were much greater in distilled water and in sulfurous acid solution than in any of the salt solutions listed (Fig. 2). Agitation in sulfurous acid (0.4 percent sulfur dioxide) and in distilled water, for 16-minute periods, resulted in losses of 16 percent and 12 percent, respectively. (Losses of around 8 percent were found in the chloride solutions under comparable conditions.) Losses from agitation in sulfurous acid solution and distilled water continued sharply upward with little tendency toward leveling off during the course of the experiments, which lasted 16 and 46 minutes, respectively.

Results for *Gravenstein transverse half-slices* (Table 2) indicated that about one-third more leaching results from transverse half-slices than from the radial slices previously described, in accord with the larger ratio of surface area to volume. In general, the same trends were found. For *whole peeled Gravenstein apples*, the results (Table 3) indicated that about half as much sugar was lost by whole apples as by radial slices.

The losses for Winesap and Pippin radial slices were similar to those for Gravenstein radial slices and showed the same general trends. The addition of 2.5 percent sodium chloride to the previously described 0.4 percent sulfur dioxide solution (estimated osmotic pressure 19 atmospheres) decreased the leaching by more than one-third after a 16-minute period. Slices soaked for 24 hours in 1.8 percent salt solution lost roughly 25-50 percent of their total sugars.

Incidental to the leaching studies, weight changes in

TABLE 3

Whole Gravenstein Apples

Solution	Initial Concentration	Treatment	Contact time	Leaching loss
	%		*min.*	%
NaCl	0.7	Soaked	10	3.7
			60	6.2
NaCl	1.8	Soaked	10	3.5
			60	4.2
NaCl	3.6	Soaked	10	3.6
			60	4.4
$CaCl_2$	1.0	Soaked	10	3.9
			60	5.4
$CaCl_2$	2.7	Soaked	10	3.6
			60	4.4
$CaCl_2$	4.6	Soaked	10	3.7
			60	4.8

TABLE 4

Apple Weight Changes (Percent)

Solution	Gravenstein			Winesap		Pippin	
	Radial slices soaked	Transverse slices agitated	Whole apples soaked	Radial slices soaked		Radial slices soaked	
	120 min.	30 min.	60 min.	120 min.	24 hrs.	120 min.	24 hrs.
0.7% NaCl	+ 8	+ 5	+ 4	+ 4	+ 5	+ 10	+ 11
1.8% NaCl	+ 5	+ 4	+ 2				
3.6% NaCl	− 1	− 1	+ 1				
1.0% $CaCl_2$	+ 9	+ 5	+ 4				
2.7% $CaCl_2$	+ 6	+ 3	+ 2				
4.6% $CaCl_2$	− 2	− 2	+ 1				
	Agitated 16 min.	Agitated 16 min.		Agitated 16 min.		Agitated 16 min.	
0.4 percent SO_2	+ 5	+ 7		+ 2		+ 9	
	Agitated 46 min.	Agitated 46 min.					
Dist. H_2O	+ 4	+ 7					
				Agitated 16 min.		Agitated 16.5 min.	
0.4 percent SO_2 + 2.5 percent NaCl				+ 2		+ 6	

the apple slices were determined. In most instances, the leached apples were found to have gained weight, even in cases where large losses of total sugar had occurred (Table 4). The weight changes ranged from a gain of 11 to a loss of 2 percent, and averaged about 4 percent. In general, apples gained more weight in dilute than in concentrated solutions. It was not practical to carry out the measurement of these weight changes with the same degree of precision which was used in the determination of leaching losses, and the results are doubtless somewhat high, due to incomplete drainage of surface liquid.

Conclusions

The leaching of sugars from apple slices by aqueous solutions ranges from a minimum loss of about 5 percent of total sugars present for an immersion time as short as one minute, to a maximum of roughly 50 percent for a 24-hour soaking period.

The leaching loss can be minimized by decreasing the immersion time, by use of as large a slice size as possible, and by avoidance of very dilute solutions (especially of sulfurous acid) as solvents.

Within practical limits, the effects due to kind of salt used, agitation of the immersion medium, and variety and maturity of apples are of secondary importance.

Since agitation is unimportant, the rate of diffusion of soluble solids from the interior of the apple slice to the surface is the rate-determining step for the leaching process.

Acknowledgment

The authors gratefully acknowledge the many helpful suggestions of R. R. Legault and W. F. Talburt of this Laboratory.

LITERATURE CITED

1. Carré, M. H., and Haynes, D. Estimation of pectin as calcium pectate and the application of this method to the determination of the soluble pectin in apples. *Biochem. J.*, **16**, 60 (1922).
2. Hackney, F. M. V. Studies in the metabolism of apples. VI. Respiration of sliced apple tissue. *Proc. Linnean Soc. N. S. Wales*, **70**, 333 (1945).
3. Hassid, W. Z. Determination of reducing sugars and sucrose in plant materials. *Ind. Eng. Chem., Anal. Ed.*, **8**, 138 (1936); Determination of sugars in plants by oxidation with ferricyanide and ceric sulfate titration. *Ibid.*, **9**, 228 (1937).
4. Hassid, W. Z., McCready, R. M., and Rosenfels, R. S. Determination of starch in plants. *Ibid.*, **12**, 142 (1940).
5. Howard, L. B., and Campbell, H. Dehydrofreezing—new method of food preservation. *Food Ind.*, **18**, 674 (1946).
6. Makower, B., Chastain, S. M., and Nielsen, E. Moisture determination in dehydrated vegetables. Vacuum-oven method. *Ind. Eng. Chem.*, **38**, 725 (1946).

Role of Bruising and Delay in the Development of Off-Flavor in Peas[a]

RACHEL UHVITS MAKOWER and ALICE COLLINGS WARD[b]
Western Regional Research Laboratory,[b] Albany, Calif.

(Received for publication, August 3, 1949)

Organoleptic studies indicate that Giant Stride and Morse's No. 60 peas (hand-shelled) require both bruising and a period of delay to produce "delay" off-flavor and deterioration of texture and color. These effects occur in the absence of microorganisms, and are accentuated by increased bruising or delay, but are not produced by bruising alone, or delay alone (for 24-30 hours at 75° F.).

Some frozen peas after being cooked have an unpleasant off-flavor known to be associated with delay between shelling of the peas in the viner and blanching *(22, 25, 28)*. Packers and graders are familiar with the characteristic odor easily recognizable in the vicinity of a blancher in which delayed peas are being processed. In a previous paper from this Laboratory, it has been called "delay" off-flavor *(28)*. For lack of a better term, we shall continue to call this off-flavor (or a combination of off-flavors) delay off-flavor.

The off-flavors in canned and frozen peas that have been called "hay-like" are possibly different and appear to be associated with under-blanching of peas and with prolonged storage *(1, 6, 7, 11, 12, 13)*.

In 1929 Gowen demonstrated that viner-shelled peas developed a strong off-flavor within 4-6 hours at room temperature *(9)*. Other studies indicated that this off-flavor is accompanied by increased toughening and calcium content of the pea skins *(2, 9, 10, 24, 25, 26)*. Flavor deterioration and toughening of pea skins increase with time of holding (delay) *(5, 8, 9, 10, 20, 23, 24, 25, 28)* and with temperature *(5, 10, 16, 22, 26, 28)*. Thoroughly cooled peas also develop this off-flavor but much more slowly *(10, 16, 22, 26, 28)*. The smaller peas appear to develop delay off-flavor more readily than the larger, more mature peas *(24, 26)*, while skin toughening due to delay is greater in the more mature peas *(2)*. Kertesz and others *(14, 16, 24)* found that bruising of peas toughens the skins and suggested that bruising may influence flavor.

Kohman *(17)* and Kohman and Sanborn *(18, 19)* were the first to demonstrate that bruising is an important factor in the development of off-flavor in peas. Bruising was also found to modify the respiration of peas, decreasing the oxygen consumed and increasing the amounts of carbon dioxide, aldehyde, and alcohol produced *(18, 19)*. It has been shown, at least with canning peas, that hand-shelled peas do not deteriorate in flavor as rapidly *(16, 17, 18, 19, 24)*, or toughen as much as do viner-shelled peas *(20, 24, 28)*, which are severely bruised. Immediate blanching of bruised or unbruised peas inactivates the enzymes, inhibits respiration and kills most microorganisms. Thus, blanching or cooking, applied without delay, prevents the deterioration of flavor and skin texture of peas.

There is a good deal of confusion in the literature

[a] Presented before the Ninth Annual Convention, Institute of Food Technology, San Francisco, July 11-14, 1949.

[b] Bureau of Agricultural and Industrial Chemistry, U. S. Department of Agriculture.

regarding the various off-flavors and their possible causes. There is some agreement, however, on the probable enzymatic nature of the processes that may lead to the development of these off-flavors *(1, 11, 12, (13, 14, 15, 16, 18, 28)*. Anaerobic respiration *(19)* and microbial action *(4, 6, 7, 22)* during the delay period have also been suggested as important causes of off-flavor.

In the vegetable freezing industry, bruising is almost unavoidable and pre-blanching delays are common. In view of the lack of appropriate quantitative information, this study was undertaken to clarify the influence of the following factors upon the development of delay off-flavor, skin texture, and color in peas under controlled conditions:

1. Controlled bruising.
2. Time of delay.
3. Presence or absence of microorganisms.

In each experiment the changes in flavor, skin texture, and color of treated peas were determined organoleptically by comparison with suitable controls.

Materials and Methods

Peas of the Giant Stride variety grown at Milpitas, California, were obtained during the fall season of 1948. After being hand-picked, the pods were heavily iced, brought to the Laboratory, and stored at 33° F. (0-1° C.). The peas for all experiments were hand-shelled and carefully hand-sized. Only sizes 3-5 were used. All scratched, bruised or otherwise injured peas were discarded before treatment was started.

The peas were bruised by tumbling 100 grams in a stoppered 500-ml. Pyrex centrifuge bottle, rotated end over end at 55 r.p.m. for a definite period. Thus, the amount and kind of bruising were well standardized. When bruised, the peas darkened in color, but were not broken or crushed.

Throughout each experiment, precautions were taken to keep the peas from undue contamination with microorganisms. All equipment was clean and dry. All peas were washed several times after shelling and sizing and were dried by blotting with a clean towel. During the period of delay the peas were placed in a single layer in large glass crystallizing dishes lined with a double thickness of filter paper. These dishes were loosely covered with watch glasses to allow for aeration. No moisture condensed upon the surfaces of the peas or the container walls. Bacterial counts on several samples held 5 to 24 hours at room temperature indicated a relatively low level of contamination.

The aseptically-handled peas were obtained by the use of sterile technique. Peas in sound, unbroken pods are apparently not contaminated by microorganisms. The selected pods were washed in alcohol, dried, and opened with sterile equipment; the peas were sized, weighed, bruised and delayed under aseptic conditions; in all other respects they were treated exactly as the non-aseptic peas used in similar experiments.

For the supplementary experiments, a large-podded market variety of peas, Morse's No. 60,[c] grown near Hayward, California, was purchased in the spring of 1949, iced, and stored 1 to 3 days at 33° F. (0-1° C.). In all experiments, these peas were treated exactly like the fall peas of the Giant Stride variety, except for a slight modification in aseptic technique; i.e., the pods were opened and the peas were handled manually rather than with sterile knives and forceps. The hands were previously washed in alcohol and dried with a sterile towel.

Bacterial counts were made on the aseptically-handled Giant Stride and Morse's No. 60 peas. No contamination was found in these peas delayed for 5½ hours after bruising under the conditions described above.

The organoleptic studies were made on the experimental 100-gram samples of peas after boiling in one-half of their weight of water for 6 minutes in covered beakers. The water had previously been boiled 5 minutes to remove carbon dioxide, in order to minimize color deterioration. The samples were coded.

Nine selected judges participated in the scoring throughout the study. Five to seven judges were present each scoring period. The judges were asked to identify the samples with "typical delay off-flavor" and in addition to score each of the following factors: off-flavor, skin texture, and color. Scores of 1 to 7 were used for each quality, 7 for no off-flavor, or very tender skin, or bright green color, and 1 for much off-flavor, or very tough skins, or gray or yellow-green color.

A control consisting of freshly shelled peas of the same size and from the same lot as the experimental material was included as an unknown in each tasting session. In most experiments, a sample bruised 30 minutes and delayed was also included as an unknown.

The average of the individual scores of each quality at a given tasting session was subtracted from the average score of the control. These differences for a series of experiments were averaged again and recorded, together with the calculated standard error. The standard errors were thus calculated from the means of single tasting sessions rather than from individual scores. Statistical analysis was made of all the organoleptic measurements.

Results

The results of the experiments are summarized in Table 1. In some cases the same data are recorded in different sections of the table in order to make immediate comparisons easier and clearer. This table shows the percent of judges who identified the "typical delay off-flavor" and the average score differences from the corresponding controls for off-flavor, skin texture, and color.[d] The variations observed in the identification of typical delay off-flavor and in the score differences, reported in Table 1, are of the same order as those usually observed in taste panel evaluations and other biological assays. For example, when 78, 83, 81, 74, 83 and 97 percent of judges identified the typical delay off-flavor, these levels of identification are actually very high, as the chi-square values indicate. In an experimental set-up of this kind, a 100 percent identification is extremely unlikely.

[c] Morse's No. 60 is a variant of the Giant Stride and is similar to it.

[d] Wherever significance is mentioned in the text it is based on the calculations of "χ^2" or "t" values at the 5% level of probability *(27)*. Chi-square and standard error values are included in Table 1.

TABLE 1

Loss of Quality in Peas Bruised and Delayed at 75° F. (24° C.) under Varying Conditions of Time and Microbial Contamination [d]

Section and Variable	Variety [e]	Bruising in Minutes	Conditions of Delay		No. of Experiments	Delay Off-Flavor		Off-Flavor		Skin Texture		Color	
			Time Hours	Bacterial Count Per Gram		% [f]	χ^2 [i]	Diff. [g]	S. E. [h]	Diff. [g]	S. E. [h]	Diff. [g]	S. E. [h]
A. Bruising and Delay	G. S.	0	24-30	.....	5	10	2.30	0.5	.13	0.9	.12	0.9	.29
	M-60	0	24	290,000-576,000	6	3	0.35	0.0	.08	0.7	.17	0.9	.14
	G. S.	30	0	.....	3	0	0.00	0.1	.23	0.4	.17	0.2	.15
	G. S.	30	5-6	10-7100	7	78	20.65	1.9	.30	1.7	.28	1.2	.24
B. Bruising Time	G. S.	0	5-6	.....	3	11	2.12	0.0	.24	0.3	.30	0.5	.35
	G. S.	10	5-6	.....	3	83	25.72	1.6	.32	1.4	.17	1.2	.35
	G. S.	30	5-6	.....	3	100	36.00	2.9	.49	2.0	.09	1.3	.22
C. Period of Delay	G. S.	30	0	.....	3	0	0.00	0.1	.23	0.4	.17	0.2	.15
	G. S.	30	5-6	.....	18	81	143.58	2.0	.18	1.6	.10	1.3	.13
	G. S.	30	18.5	.....	3	74	18.54	3.4	.58	2.5	.27	3.1	.35
D. Aseptic Handling	G. S.	30	5.5	0-0	2	83	17.20	2.2	.85	1.0	.20	1.4	.20
	M-60	30	5.5	0-0	6	97	64.50	4.0	.15	1.8	.14	2.2	.18

[d] Loss of quality as measured by difference in scores between freshly-shelled and experimentally-treated peas.
[e] Varieties: G. S. = Giant Stride; M-60 = Morse's No. 60.
[f] Percentages of judges who indicated the presence of typical delay off-flavor in samples.
[g] Difference in scores between freshly shelled and experimentally-treated peas, i.e. differences from controls.
[h] S. E. = Standard Error of the differences from controls.
[i] Significance at probability of 0.05 (5%) or better is indicated by chi-square values of 3.84 or higher.

Unbruised, carefully hand-shelled peas, held up to 30 hours, were found by most judges to be free of "typical delay off-flavor" (Table 1, A). In many cases, the judges rated the peas delayed for 24 to 30 hours to be almost as free from off-flavor as the freshly shelled controls, but they did find a significant deterioration of skin texture (Table 1, A, Line 1). The results were particularly clear-cut with the unbruised peas of the variety Morse's No. 60, delayed 24 hours at room temperature (Table 1, A, Line 2 and Figure 1).

Peas cooked immediately after bruising were free of delay off-flavor and did not differ significantly in flavor, skin texture, or color from the corresponding controls (Table 1, A, Line 3 and Figure 1), while peas in the same series, similarly bruised, but delayed for 5-6 hours at room temperature (Table 1, A, Line 4 and Figure 1), were decidedly inferior to the controls.

For the same period of delay (5-6 hours) at 75° F. (24° C.) the amount of delay off-flavor, as indicated by the number of judges who recognized it, increased with the time of bruising (Table 1, B). The differences in off-flavor from the controls increased from zero to 2.9, when the bruising time was varied from zero to 30 minutes. A similar trend was observed with the ratings of skin texture and color.

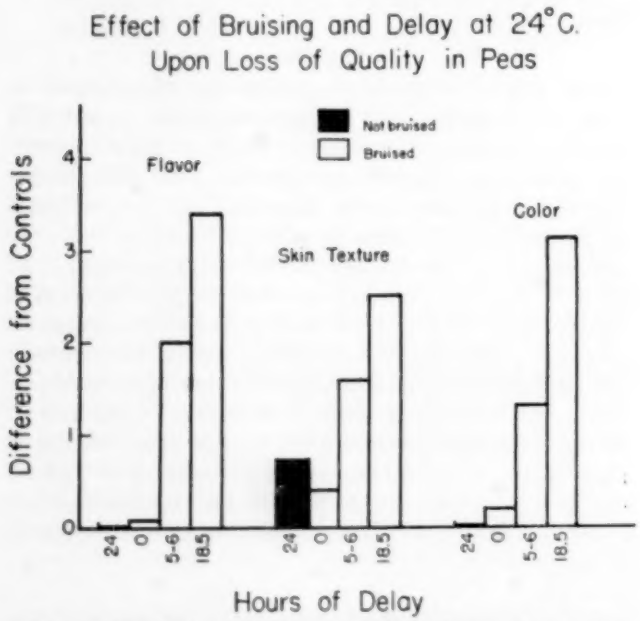


FIG. 1. The first column in each graph (flavor, skin texture, and color) refers to peas of variety Morse's No. 60 delayed for 24 hours, but not bruised. All of the other columns refer to experiments with peas of the variety Giant Stride.

Increasing the delay at 75° F. (24° C.) of peas bruised for 30 minutes also magnified the amount of off-flavor and resulted in a corresponding drop in quality of the skin texture and color of bruised and delayed peas (Table 1, C and Figure 1). Thus, the peas held at room temperature for 18½ hours had more off-flavor, tougher skin texture, and poorer color than did the bruised peas held only 5-6 hours, while the peas cooked immediately after bruising had no off-flavor and were in all respects almost as good as the controls.

The results of bruising and delay of peas kept under aseptic conditions are reported in Table 1, D. The great majority of judges identified a typical delay off-flavor in these peas, although the bacterial counts on all samples were zero. The amount of off-flavor measured by difference from controls was particularly high in Morse's No. 60 samples. The differences in skin texture and color were also pronounced. Very similar, though less striking, results were obtained with Giant Stride peas under aseptic conditions. The results of experiments with Giant Stride peas were considered unreliable, because only two trials were made and the standard error was high. Therefore, a repetition of this study was made with the variety Morse's No. 60, as reported in Table 1, D.

Bacterial counts were made on the unbruised (carefully hand-shelled) peas of Morse's No. 60 delayed for 24 hours at room temperature. As shown in Table 1, A, these counts are fairly high, varying from 290,000 to 576,000 per gram of peas, yet the scores for flavor and color were no different from the controls.

Discussion

It is clear from the results that bruising of peas is a major factor in the development of delay off-flavor. It is equally clear that bruising alone (without an interval of delay) does not result in the production of a detectable amount of delay off-flavor. Furthermore, delay without

bruising, even for as long a period as 24 to 30 hours at room temperature, does not produce typical delay off-flavor. It must be concluded, therefore, that neither bruising alone nor delay alone is sufficient for the formation of delay off-flavor in peas.

The conditions that influence the development of delay off-flavor in peas suggest that it is the result of an enzymatic reaction or reactions. It is possible that the reactions in question are related to anaerobic respiration, as has been suggested *(19)*. Our experiments do not contradict such a possibility.

The activity of microorganisms in shelled peas held before processing has been suggested as a probable cause of off-flavors *(4, 6, 7, 22)*. There is no doubt that bacterial decomposition readily produces objectionable flavors and is very likely to occur in peas held at room temperature for extended periods of time. But the characteristic delay off-flavor was recognized in bruised peas kept free of microorganisms. At the same time, this off-flavor was absent from unbruised peas held for 24 hours at room temperature in the presence of a considerable bacterial population. These experiments demonstrate that the production of the characteristic delay off-flavor in peas is unrelated to the presence or absence of microorganisms.

Inasmuch as bruising is unavoidable in the methods currently employed for processing peas, it is important to consider practical measures of controlling the excessive development of delay off-flavor. The possibility of improving harvesting and vining equipment and procedures has been mentioned by Talburt and Legault *(28)*. The detrimental effects of bruising can be minimized by shortening the delay period and by immediate and thorough chilling of the peas after vining. The beneficial effect of chilling has been previously demonstrated *(10, 16, 22, 26, 28)*; it is known, however, that chilling merely retards the deteriorative processes, but does not stop them. Therefore, the best quality peas will be obtained by processing immediately after vining with little if any delay.

Summary

In a series of experiments with Giant Stride and Morse's No. 60 peas, it was found that:

1. Considerable off-flavor is produced by keeping bruised peas at 75° F. (24° C.) for 5 to 6 hours. Skin texture and color also deteriorate on bruising and delay. Neither bruising alone nor delay alone (without bruising) is sufficient for the development of delay off-flavor in peas.

2. Bruised peas develop delay off-flavor in the absence of microbial growth.

3. Unbruised peas, delayed at 75° F. (24° C.) for 24 to 30 hours, failed to develop a typical delay off-flavor, although the bacterial count was as high as 576,000 per gram.

4. Increasing extent of bruising or time of delay tends to increase the off-flavor in bruised and delayed peas.

Acknowledgment

The authors are indebted to Mildred M. Boggs and H. K. Burr for many helpful suggestions and for aid with the statistical work.

BIBLIOGRAPHY

1. Arighi, A. L., Joslyn, M. A., and Marsh, G. L. Enzyme activity in frozen vegetables. *Ind. Eng. Chem.* **28**, 595 (1936).
2. Boggs, M. M., Campbell, H., and Schwartze, C. D. Factors influencing the texture of peas preserved by freezing. I. *Food Research* **7**, 272 (1942). II. *Food Research* **8**, 502 (1943).
3. Boggs, M. M., and Talburt, W. F. Comparison of quality of frozen and dehydrofrozen peas with fresh and stored pod peas. Manuscript.
4. Campbell, H. Factors influencing selection and pretreatment of vegetables for freezing. *Food Packer* **27** (8), 41; (9), 52 (1946).
5. Campbell, H., and Diehl, H. C. Quality in frozen pack peas. *Western Canner and Packer* **32** (10), 48; (11), 51 (1940).
6. Daughters, M. R. The flavor and texture of frozen vegetables. *Quick Frozen Foods* **9**, (5): Part I-II (following. p. 66.) (December 1946).
7. Diehl, H. C., Campbell, H., and Berry, J. A. Some observations on the freezing preservation of Alderman peas. *Food Research* **1**, 61 (1936).
8. Gorrell, F. E. Toughening of peas. *Canner* **82** (11) Part 2, 26 (1936).
9. Gowen, P. L. Effect on quality of holding shelled peas. *Canner* **66**, 112 (1928).
10. Gowen, P. L. Blanching of peas. *Canner* **68**, 100, 103 (1929).
11. Joslyn, M. A. Preservation of fruits and vegetables by freezing storage. Calif. Agr. Exp. Sta. *Circ.* **320** (1930).
12. Joslyn, M. A., and Marsh, G. L. The rôle of peroxidase in the deterioration of frozen fruits and vegetables. *Science* **78**, 174 (1933).
13. Joslyn, M. A., and Marsh, G. L. Changes occurring during freezing storage and thawing of fruits and vegetables. Calif. Agr. Exp. Stat. *Bull.* **551** (1933).
14. Kertesz, Z. I. The chemical changes in peas after picking. *Plant Physiol.* **5**, 399 (1930).
15. Kertesz, Z. I. Inactivating the respiration of cannery peas by heat. *Canner* **76**, (11), 7 (1933).
16. Kertesz, Z. I., and Green, E. L. Deterioration in shelled green peas held a few days in storage prior to canning. *J. Agr. Research* **45**, 361 (1932).
17. Kohman, E. F. New factors relating to quality in canned peas. *Canner* **74**, (11): Part II, 64 (1932).
18. Kohman, E. F., and Sanborn, N. H. Special chemical studies. Enzymic activity in peas. *Canner* **74**, (11): Part II, 132 (1932).
19. Kohman, E. F., and Sanborn, N. H. Effect of respiration on vegetable flavor. *Ind. Eng. Chem.* **26**, 773 (1934).
20. Kohman, E. F., and Sanborn, N. H. Special chemical studies. Experiments with peas. *Canner (Convention)* **82**, (11) Part 2, 110 (1936).
21. Lutz, J. M. Evaluating quality changes in certain vegetables after harvesting. *Proc. Am. Soc. Hort. Sci.* **36**, 754 (1938).
22. Nielsen, J. P., Wolford, E. R., and Campbell, H. Delay affects frozen pea quality. *Western Canner and Packer* **35**, (6), 47 (1943).
23. Pollard, L. H., Peterson, H. B., and Wilcox, E. B. Influence of stage of maturity on the yield and quality of Perfection peas. *Western Canner and Packer* **36**, (6) 19 (1944).
24. Sayre, C. B., Willaman, J. J., and Kertesz, Z. I. Factors affecting the quality of commercial canning peas. N. Y. Agr. Exp. Stat. (Geneva) *Tech. Bull.* **176** (1931).
25. Schwartze, C. D., Rundle, C. H., Boggs, M. M., and Campbell, H. T. Relationship of yield to quality of frozen peas. West. Wash. Agr. Stat. *Rept. 1940*, p. 34.
26. Smith, H. R. Special investigations. Effect of holding vine peas in cold storage. *Canner* **70**, 211 (1930).
27. Snedecor, G. W. *Statistical Methods.* The Iowa State College Press, Ames, Iowa, 61 (1946).
28. Talburt, W. F., and Legault, R. R. The effect of delay on shelled peas. In press *(Food Industries)*.

Some Advances in the Production of Edible Oils and Fats[a]

HAROLD S. MITCHELL
Swift & Co., Chicago, Ill.

(Received for publication, July 25, 1949)

(REVIEW PAPER)

A number of the important performance requirements of shortening are discussed. The various steps in the building of shortenings from edible fats and oils are described with particular emphasis on some of the more important improvements in processing methods.

Man, since his earliest existence, has utilized the naturally occurring foods of both animal and vegetable origins with their natural content of fat. As the value of fats and oils themselves became apparent, he became interested in obtaining, purifying, and adapting them to his use. Man's progress in this regard has followed a typical course. Starting with the fruits, the seeds, and the animal foods, he has first separated the fats and oils grossly from the accompanying husks, pulp, and flesh; then he has learned to cleanse and purify the fats and oils, to blend them, and finally to alter their chemical composition and their physical properties. This evolution in technology has proceeded a step at a time. Sometimes the steps have been widely separated; at other times they have followed in rapid succession. The story of the development of edible fats, changing as it did since the time of primitive man with the habits and requirements of the human race, is an extremely interesting one. It can be referred to here, however, only as a subject for later consideration.

The present-day methods of obtaining and processing fats and oils for edible purposes have reached a high state of development. Raw materials varying appreciably in purity and composition are being built into shortenings suitable for a large number of uses. It is the purpose of the present article to present information about the requirements of the consumers of these edible fats in the form of shortenings and about the outstanding technological advances which have been made in the methods of handling the raw materials.

Characteristics

The more important performance characteristics of edible fats in the form of shortenings may be summarized briefly as follows:

Color. The color should be white with but a slight tinge of cream. Although the normal color range of shortenings would not exert any influence on the final baked product, this characteristic is of considerable importance as it apparently is used by the consumer as an index of purity.

Flavor. Some fats such as butter, margarine, lard and oleo oil contribute a natural flavor in cooking and baking. Processed fats, however, have a bland flavor and must not carry undesirable flavors as they would be detrimental to the finished flavor of the final product.

Consistency. The shortening should be readily mixable under the conditions of use, and the temperature range of mixability should be wide.

Creaming Quality. Creaming quality represents the ability of a fat to entrap air when vigorously agitated with sugar alone or with sugar and water. The expansion of this air in a cake batter during the baking of the cake contributes appreciably to the volume and inside characteristics of the finished product. This property also influences the ability of the shortening to perform well in the making of icings.

Emulsifying Property. The emulsifying property of a shortening influences its ability to disperse in liquid mediums. An important method of increasing this property and thus the ability of the shortening to permit the addition of high percentages of milk, eggs, and sugar in cake production is to add small amounts of mono- and diglyceride shortenings. These are assimilable fats occurring in small quantities in practically all natural fats and oils.

Keeping Quality. Shortenings must have high resistence to reactions which lead to rancidity or reversion. Satisfactory keeping quality gives satisfactory shelf life both to the shortening in the consumer package and to baked goods such as crackers, cookies, prepared mixes, etc., in which it is used by the baker and other food processors.

Stability to Heat. Fats used for deep-fat or pan frying must withstand high temperatures without abnormal decomposition. The flavor should remain satisfactory, and there should not be excessive smoking. In commercial frying operations, as in the production of doughnuts and potato chips, the fat is subjected to long periods of rather high temperatures. Stability of the frying fat is very important under these conditions, although the proper care of the frying medium is equally important.

Nutritive Value. Fats play an important part in the human dietary. They are the richest and most concentrated foods known to man, so their use in baked goods improves the dietary value of the finished products. Shortenings containing certain unsaturated fatty acids have been found to have some slight nutritive advantage, but with respect to digestibility and caloric values there is little difference between any of the better shortenings.

The technology of building shortenings from edible fats and oils to meet the preceding requirements is both extensive and complex. Before consideration of each production step in detail and in the order of occurrence, as well as the improvements which have been made, attention should be called to three significant points:

1. None of the natural fats or oils has all of the qualities needed for all of the uses of shortenings. Even after processing there is no all-purpose shortening, particularly for the baking trade.

[a] Presented before the Ninth Annual I. F. T. Convention, San Francisco, California, July 11, 1949.

2. All edible fats and oils are good ingredients for shortening. Their origin, whether it be animal or vegetable, is of no consequence.

3. The ability of a finished shortening to perform the tasks required of it depends to a considerable extent on the technological skill and facilities of the manufacturer.

Meat Food Fat Shortening

The most important step in the production of this type of shortening is the removal of the fat from its natural carrier. With meat food fats the "melting out" or "rendering" is a rather simple operation following closely in principle the home custom of separating fat by heating in a suitable container on the kitchen stove. Research to improve this process has dealt primarily with the elimination of odors and flavors, improvement of quality by more efficient rendering methods, better selection of raw materials, and increase in yields. Steam rendering, or the cooking of fats such as lard under steam pressure in the presence of water, has been in use for many years. Proper selection of the raw material together with careful control of the pressures and the time of cooking has led to the production of a product low in free fatty acid, light in color, and with a very satisfactory mild lard flavor. "Dry rendering" under vacuum has come into use to some extent. This procedure increases the yield but leads to a product with a somewhat more cooked flavor than the steam rendered lard.

Open kettle rendering is still used, of course, in the preparation of two types of lard, one designated as "neutral" and the other "kettle rendered." In the first, the temperature attained in the steam-jacketed kettle used is comparatively low so that little flavor is cooked out of the "cracklings," but a considerably higher temperature is used for the production of the kettle-rendered product, resulting in a rather strong but pleasing cooked flavor.

The open-kettle rendering process at low temperatures is used also for the rendering of oleo stock from beef fat. This is the raw material from which oil is expressed, leaving behind the harder portion of the stock known as oleo stearine. The oil is used rather extensively by the biscuit and cracker trade, and both the stock and the stearine are excellent raw materials for making blended type shortenings.

Proper selection of raw materials, prompt handling of these materials, close following of carefully developed rendering conditions, together with the use of an internal method of chilling in place of the old fashioned chill roll, have resulted in the production of lard which is quite satisfactory for many cooking and baking purposes both in the home and in the bakeshop. Hardened lard is usually added to increase the plastic range, particularly at higher temperatures. Lard has a natural flavor considered very desirable by many. It has high shortening power and is used quite extensively in baked goods such as pies and crackers where flakiness and crispness are important. Lard is also a preferred shortening for bread.

Recent use of antioxidants has improved the stability of lard considerably. The result has been a greatly increased shelf life and a greater resistance to the development of off flavors in cooked or fried foods. The more important antioxidants which have been approved for use in lard are gum guaiac, propyl gallate, butylated hydroxy anisole and nordihydroguaiaretic acid. These products, when present in minute quantities, will increase the keeping quality of lard from 3 to 20 times.

Variation in the quality of lard over a period of years together with extensive promotional campaigns in the interests of the processed shortenings has influenced the preference of some consumers in favor of the bland type products. Certain manufacturers have met this change by the development of a processed bland type lard for the consumer trade which compares very favorably in every respect with the best of other processed products. It creams well, is satisfactory for the recently advocated quick mix cakes, and can be used for frying. The use of antioxidants gives these products long shelf life. The new type lard retains the high shortening power of natural lard. Like regular lard, it is digestible and nutritious, too.

Processed Shortenings

The processed shortenings may be made from meat food fats, from vegetable oils, or from mixtures of the two. It should be emphasized again that all edible fats are suitable for processing into shortenings for either bulk or consumer use. Preference claims, either actual or inferred, of one class of product over another cannot be substantiated by valid scientific research findings.

Extraction. The methods of extraction of the meat food fats have been described previously. The separation of the vegetable oils from their natural carriers is somewhat more complicated. Precooking and use of high pressure in expressing the oil from oilseeds have been used for many years. Hydraulic presses have been superseded to a considerable extent by continuous screw presses, which are more efficient and produce oil of a somewhat better quality. Solvent extraction has assumed importance in the past few years and has proved to be the most successful method for processing soybeans. In fact, it is beginning to be used for cottonseed. The amount of oil left in the meal with this method is considerably less than with either the hydraulic or continuous screw-pressing methods. The solvent method is quite attractive, therefore, especially where it can be operated in the center of large supplies of raw materials.

Refining. Meat food fats, if properly rendered and processed, may be used without refining, either as shortenings or as raw materials for shortenings. The vegetable oils as expressed by the several methods, however, contain appreciable amounts of impurities such as free fatty acids, coloring matter, gums, resins, etc. A purifying step is required, therefore, which is referred to as "refining" by the processors of the crude oils. Caustic alkalis have been used in the refining step since about the middle of the 19th century *(9)*. The practice followed for years was to mix oil and slightly more than enough caustic soda to neutralize the free fatty acids, with gentle heating, until a distinct separation took place, and then to allow the soapstock or "foots" to settle. The soapstock was withdrawn, and the oil was

pumped from the vessel. This procedure required such highly experienced operators for success that the process might well be considered an art. In the early 1930's *(6)* the refining process was made continuous by introduction both of proportioning equipment to mix the oil and caustic in controlled amounts and of high speed centrifuges to separate the soapstock from the oil continuously. This resulted in a more accurately controlled process with lower refining losses, and the entire industry was soon largely converted to this method.

About ten years ago a two-stage method *(3, 8)* was introduced which consists in mixing the oil with soda ash solution, separating the foots by centrifuging, then washing with a strong solution of caustic soda, and finally centrifuging again. This method is said to operate with a lower loss of oil than the single-stage procedure and appears to be replacing it.

It is common practice in both of the alkali refining methods which have been described to wash the refined oil by mixing it with water and then centrifuging to remove the final traces of soap and alkali. Vacuum drying then removes any small amounts of water remaining.

The use of certain solvents to remove impurities from crude oils has been under consideration for several years. Liquid-liquid extraction by means of furfural, in conjunction with a non-polar hydrocarbon solvent *(4)*, has been practiced on a small scale. Another system makes use of liquid propane *(5)* as a selective solvent. These methods are not in general use at present, but they show some promise of practical application in the field of edible oils.

Bleaching. The refining procedures do not lead in most cases to a sufficiently light color in the oils to produce the whiteness desired in the finished shortening, so additional treatment is required. Exposure to light, blowing with air *(10)*, use of chemical bleaches, and treatment with charcoal are recorded as methods in use in years past. Natural earths classified as "Fullers Earth," however, were found sometime during the latter part of the last century which, when mixed with the refined oil and heated, would remove most of the remaining color by adsorption. Continuing improvement of these earths resulted from the discovery of more active deposits and from increased knowledge as to proper fineness and conditions of use. It was discovered still later that treatment of certain natural earths with mineral acids, such as sulfuric, greatly increases the adsorptive power. Such products are known as activated earths, and it is thought that they owe their greater bleaching power to the larger surface area resulting from the solvent action of the acid on certain of the mineral constituents of the earth.

Carbons of several types have been used for many years, usually in combination with either natural or activated earths, for color removal. It is supposed that the carbons are selective for certain color pigments of the oil not adsorbed by the natural or activated earth. The carbons also have been improved in bleaching ability by various methods of activation. Because of their comparatitvely high cost and high oil retention, however, their use is limited largely to difficultly bleachable oils.

In order to prevent oxidation which occurs during the usual bleaching procedure conducted in an open tank, vacuum processes have come into favor. It is possible to bleach batchwise in a vacuum tank equipped with proper agitation, but a continuous vacuum bleaching system *(7)* recently has been developed which is said to produce better quality oils with lower overall bleaching costs.

Hardening to Proper Consistency. The next step in the production of shortenings is the development of the proper degree of hardness in the fat to suit the purpose for which the product is to be used. This can be done by blending fats of different degrees of hardness or by treatment of the softer fats by hydrogenation. The latter increases the hydrogen saturation of the softer portions of the fats, thus increasing the hardness.

Hydrogenation of edible fats at present is largely a batch process. The fat, catalyst, and hydrogen are contacted in closed vessels in which such factors affecting the reaction between the fat and hydrogen as temperature, pressure, and agitation can be controlled. Each processor has developed a procedure which is the best, in his opinion. The method, therefore, is surrounded with great secrecy. The success of his process depends entirely, of course, on the ability of his final product to perform in the use to which it is put.

In England, Bolton and Lush *(2)* have developed a system of passing oil continuously over a bed of nickel turnings which have been oxidized by "anodic oxidation" and then reduced with hydrogen. The process does not have wide application. Experimental work has been and is being carried on in which powdered catalysts and oil are contacted continuously. Much remains to be done before such processes become practical.

Perhaps more significant than the improvements in the hydrogenation process itself are the developments in the manufacture of hydrogen and catalysts. Electrolytic hydrogen was first used, but electrolysis has been replaced by other methods except possibly where electric power is cheap and coal scarce. The steam-iron process, which now supplies most of the hydrogen for fat hardening in the United States, has been improved in efficiency and made fully automatic and considerably safer than it was originally. Also, hydrogen purification systems have been developed in which carbon monoxide and sulfur compounds are removed catalytically.

Other processes used for the production of hydrogen are:

1. The water gas catalytic method in which blue gas and steam are passed over a heated catalyst to form carbon dioxide and hydrogen. The carbon dioxide is scrubbed out with organic amines.

2. Hydrocarbon reforming process in which methane, ethane, or propane is passed over catalysts to produce hydrogen and carbon dioxide. The carbon dioxide is removed by scrubbing with amines.

In both of these processes the hydrogen finally is highly purified by passing it over catalysts and through scrubbers.

Important progress has been made also in the production of catalysts for hydrogenation. Improved manufacturing methods, the use of promoters, and control of particle size have contributed to more selective and active catalysts which have in turn made possible the production of improved hydrogenated fats and oils.

Blending. During the latter part of the 19th century lard was the universal shortening. Butter, beef fat, and a number of vegetable oils were used to some extent for cooking and baking, but lard was accepted as the standard product for these purposes. As very often happens with a standard product of this kind, various manufacturers other than those producing lard began to adulterate the product. Cottonseed oil, beef fat, and beef stearin were the adulterants usually used. Strong objections to this practice were raised, and during the period of about 1890 to 1910 many state statutes were passed which required that the adulterated lard must be plainly labeled as "lard substitute" or adulterated lard" or "compound" or "imitation" or "blend" and that further the purchaser must be advised that the article sold was "lard substitute" or "adulterated lard" or "compound," etc. As a result of this legislation, secret adulterations of lard were finally abandoned, and there came into existence a class of products known during this period as "lard substitutes." These consisted principally of mixtures of lard with beef stearin, beef fat, and cottonseed, corn, peanut, sesame, cocoanut, and palm kernel oils. Notwithstanding the adoption of laws which had prohibited the sale of these products as lard, certain manufacturers, at that time, still endeavored to retain the connection with lard with the result that the new products were called "compound lard" or "lard compound." The great majority of these mixtures did not contain any lard at all. The mixtures used finally narrowed down to cottonseed oil and beef stearin. The introduction of the process of hydrogenation in about 1908 made possible the production of another hardening agent for the mixed type product and another "lard substitute" for that period in the form of the all-hydrogenated shortening.

Great progress has been made by the chemist and technologist in the manufacture of the mixed type shortening, or the "blended shortening" as it is now known. We have learned much about the interchangeability of fats and how to take advantage of the variations in hardness of the natural products. The meat food fats for example are suitable as such for use in shortenings. The vegetable oils on the other hand are very soft. Combinations of the two with proper quantities of hardening fats, such as oleo stearin or oils hydrogenated to proper consistency, are being made which will function quite as satisfactorily as the all-hydrogenated products. These physically blended shortenings are now used very extensively both in the home and in the commercial field. Their use seems certain to increase appreciably in the future, as the consumer recognizes the improvements which have been made and realizes their ability to perform economically and well in practically every household or bake shop use.

Deodorization. Processed shortenings must be bland in flavor and odor. It is necessary, therefore, to remove the very small quantities of constituents which impart the flavors and odors existing in the fats as they reach this stage of their manufacture. This is accomplished by deodorization, which is in reality simply a washing out of volatile materials by steam at high temperatures and in the absence of air. Deodorization was first accomplished by heating fats in boiling water and blowing steam through them. Next, fats were heated in open vessels while high pressure steam was blown through. David Wesson *(11)* was apparently the first to employ vacuum, which is the basis of the process employed today. Most deodorization now is done in batches of 20,000 to 30,000 pounds of fat in cylindrical welded steel vessels. They are equipped with steam ejectors and condensers to maintain absolute pressures of 5 to 10 mm. Some simple form of blowing-steam distributor is employed. A number of proposed elaborate means of dispersing this steam have not proven practical. The oil is heated by passing high pressure steam or Dowtherm vapor through closed coils within the deodorizer.

Improvements in the batch process include tighter vessels to exclude air, better and more efficient vacuum equipment, and the employment of higher temperatures.

Theoretically, less steam is required if the deodorization is carried out continuously in such countercurrent manner that the oil richest in volatile materials is contacted with the steam which is most nearly saturated with these materials. This is accomplished by passing oil downward in packed or bubble-cap columns against rising steam. Such systems effectively deodorize fats with less steam than batch systems but have certain disadvantages. One is that the hold-up in the vessel makes it difficult to change charge stocks. Another is that there is less color reduction than in the batch system.

Recently Bailey *(1)* reported on a semi-continuous deodorizer in which fat is heated in trays or pans within an enclosed shell. The fat passes downward through the vessel from one tray to another while being heated in the top tray, steam-washed in the middle ones, and cooled in the bottom tray. This procedure is said to overcome the difficulty in changing feed stock and to operate more economically than the batch method.

Chilling. The hardening processes of blending and hydrogenation previously described result in a combination of hard, medium hard, and soft fats which will furnish not only the proper consistency in the finished shortening but also the ability to meet the several requirements for shortenings mentioned earlier. It is necessary, however, to chill the hardened fat after deodorization in such a way that the required plasticity and creaming ability are imparted to the shortening in the package. The most important feature of this operation is the rapidity of chilling necessary to form the proper crystal structure for the purpose required. The first attempts to produce the smooth plastic fats were made by agitation in open tanks equipped with cooling coils or jackets. Later large cylindrical rolls cooled with either brine or ammonia were used to obtain the instantaneous crystallization needed. The chilled

product drops from these rolls into a picker pan where it is mixed and a desired amount of air is incorporated. It passes to the end of the picker pan where it is picked up by high pressure pumps which deliver it to the package. The air is finely distributed throughout the product in the course of this handling and contributes to the apparent whiteness of the packaged shortening.

The latest development in the chilling procedure makes use of internal chilling units. Here the instantaneous chilling occurs in a jacketed cylinder equipped with suitable agitation and scrapers to keep the cooling surface clean. The cooling medium in the form of ammonia is applied to the products through the jackets. This method of chilling has a number of advantages. The units are compact and readily cleaned, the chilling and filling temperatures can be controlled within much closer limits than with the rolls, and definite amounts of air or inert gas may be injected into the cylinder for mixing with the product. The very general adoption of the internal type chilling equipment has greatly simplified and improved this important and final step in the production of plastic shortenings.

Summary

The technological advances in the handling of shortenings over the past few years have been many and important. They have given us improved lard with its several natural advantages, new bland lard products equal in quality to the best of the shortenings, blended shortenings made by proper mixing of fats of different hardness which deserve a high place in the list of quality products, and changes in hydrogenated shortenings which have improved them for certain new baking procedures advocated for the baker and the housewife.

LITERATURE CITED

1. Bailey, A. E. The semi-continuous deodorization of fats. Paper presented at 22nd Fall meeting, American Oil Chemists' Society (Nov. 17, 1948).
2. Bolton, E. R. Recent advances in the hydrogenation of oils. *J. Soc. Chem. Ind.*, **46**, 444 T (1927).
3. Clayton, B. (assignor to Refining, Inc.) Refining animal and vegetable oils. *U. S. Patents* 2,190,593 and 2,190,594 (Feb. 13, 1940).
4. Freeman, S. E. (assignor to Pittsburgh Plate Glass Co.). Extracting and refining glycerides. *U. S. Patents* 2,200,390, 2,200,391 (May 14, 1940).
5. Hixson, A. W., and Bockelmann. Liquid-liquid extraction employing solvents in the region of their critical temperatures. *Trans. Am. Inst. Chem.*, **38**, 891 (1942).
6. James, E. M. A new continuous process for the refining of vegetable oil. *Oil & Soap*, **11**, 137 (1934).
7. King, R. R., and Wharton, F. W. Continuous vacuum bleaching of fatty oils. *J. Am. Oil Chem. Soc.*, **26**, 389 (Aug. 1949).
8. Mattikow, M. A new method of refining oils with non-saponifying alkalies—The Clayton Process. *Oil & Soap*, **19**, 83 (1942).
9. Weber, G. M., and Alsberg, C. L. *The American Vegetable Shortening Industry*. Food Research Inst., Stanford Univ., Calif. (1934). p. 251.
10. Weber, G. M., and Alsberg, C. L. *The American Vegetable Shortening Industry*. Food Research Inst., Stanford Univ., Calif. (1934). p. 253.
11. Weber, G. M., and Alsberg, C. L. *The American Vegetable Shortening Industry*. Food Research Inst., Stanford Univ., Calif. (1934). p. 258.

Dehydration of Date-Tree Juice

A. N. BOSE and A. C. MAJUMDER

Food Technology Laboratory, College of Engineering and Technology, Jadavpur, W. Bengal, India

(Received for publication, August 4, 1949)

Sweet juice from the date-tree is dried to a moisture content of 5 percent with a double-drum drier. The dried product retains the flavor and the nutrients of the fresh juice remarkably well. For best results, the pH of the fresh juice should be about 7.2, and the steam pressure inside the drums and the speed of the drums should be kept at 40 p.s.i.g. and 12 r.p.m., respectively.

Introduction

A sweet, delicious juice obtainable from the date-tree is well-known to the people of India from time immemorial. The juice is tapped from the date-tree in the following way: In the month of October after the rains have completely stopped, the cultivator cuts off the lateral leaves on one side of the tree (usually the eastern side), exposing a white surface approximately 12 inches by 12 inches. The color of the white surface changes gradually to brown and takes on the appearance of a coarse matting in about two weeks' time. Toward the end of the browning period the whole surface becomes moist, with dew-like drops appearing on it. This indicates the beginning of the juice secretion. A cut is made on the exposed surface in the shape of a broad "V," about 3 inches across and ¼ inch deep. The juice exudes from the surface of the cut and runs down the two arms of the "V." An earthenware collecting pot is suitably tied to the trunk of the tree to catch the juice from the end of the spout. The pot is tied to the trunk of the tree in the evening and is removed, together with the juice collected in it, in the early morning of the following day. The collection of juice is carried on for three successive nights after the "V"-shaped cut is made. Then the tree is allowed to rest for two or three days. Thereafter the surface is scraped and another "V" is cut, just above the former one, and the process is repeated. The season lasts for about four months.

The juice obtained by the method described above has a sweet, pleasing flavor and is rich in minerals, thiamine, and ascorbic acid. The juice is much valued but, as it is easily fermented, its use as a drink is limited. In India, the juice is generally concentrated to a sirup or dried to a solid product (gur). The solid product is more desirable for long-time storage. It is either con-

TABLE 1

Composition of fresh date-tree juice collected on different nights after the "V" cut

Sample No.	Night	pH	Water content	Total solids	Reducing sugar	Sucrose	Protein (N × 6.25)	Ash
			%	%	%	%	%	%
1	1st	6.8	86.3	13.7	2.56	10.65	0.29	0.12
2	2nd	6.8	86.3	13.6	2.56	10.65	0.29	0.12
3	3rd	6.8	86.3	13.7	2.56	10.64	0.29	0.13

sumed as such or is incorporated in foods for flavoring and sweetening purposes.

The general method employed for producing the dried product is open-pan boiling of the juice to the desired moisture content. The method is time-consuming and requires large evaporating basins. During the season, the amount of juice collected in a day can often not be evaporated quickly enough before active fermentation starts, and consequently a large amount of this valuable juice is wasted. Moreover, the product from open-pan boiling loses most of the original flavor and nutrients of the fresh juice. Hence it was considered desirable to find some quick method of dehydrating the juice so as to prevent wastage.

Experimental

In this investigation, dehydration of date-tree juice with a double-drum atmospheric drier has been tried. The drier was fabricated by the American Machine Company, Garwood, Illinois, U. S. A. It has rolls, each of which is 72 inches long and 28 inches in diameter. There are arrangements for varying the temperature and the speed of the rolls and also for varying the distance between the rolls. Feed is introduced from the top through a perforated feed pipe between the rolls. A thin film, the thickness of which is equal to half the distance between the rolls, is carried on the surface of each of the rolls, which rotate in opposite directions (the right-hand roll, looking from the drive-end, rotates counter-clockwise). The dried film is scraped from the surface of the rolls by sharp doctor-blades, which are placed near the top of the rolls. The length of the arc between the point of contact of the doctor blade with the roll and the point of minimum distance between the rolls is approximately one-fourth the circumference of the roll.

It is generally believed that the composition of the date-tree juice varies with the time of collection after the "V" cut is made, the juice becoming gradually poorer in quality. Table 1 gives the average composition of the juice collected on different nights after the cut.

It will be found that the composition of the samples of juice collected on different nights shows negligible variation. However, it has been observed that if the juice is stored, its pH gradually decreases to 6.2, its reducing sugar content increases to 3.7 percent, and there is a marked alteration in flavor. At this stage, alcoholic fermentation also becomes vigorous. The supposed gradual degradation in the quality of the juice collected on subsequent nights may be attributed to the fact that the earthenware pots used for collection become increasingly more heavily contaminated, and consequently undesirable microbiological action on the juice sets in more quickly. With well-washed, previously sterilized earthenware pots, the juice collected in them shows negligible variations in the composition, flavor, and physical characteristics.

Standards for Organoleptic Test

As has been mentioned previously, in India the dehydrated date-tree juice is eaten as such or is incorporated in foods for flavoring and sweetening purposes, without reconstitution of the product to its original moisture content. Hence in order to compare the products of experimental dehydration with regard to their color, flavor, and texture, it was considered desirable to set up arbitrary standards with the best samples of dehydrated date-tree juice available. For this purpose, fifty best samples of dehydrated date-tree juice were collected, and a grade 10 was fixed for the best color, flavor, or texture and grade zero for the worst. Experimental samples were graded against the above-mentioned arbitrary standards.

Results

Effect of dehydration temperature: In the first series of experiments, samples of fresh date-tree juice having an average composition the same as that of samples 1, 2, and 3 in Table 1 were dehydrated with varying steam pressure in the rolls. The distance between the rolls and the speed of the rolls were fixed at 0.064 inch and 13 r.p.m., respectively. The dehydration results are shown in Table 2. As it was observed that samples 1, 2, and 3 showed similar drying characteristics, the results obtained with sample 1 only have been shown in Table 2.

TABLE 2

Effect of dehydration temperature

Steam pressure in the rolls	Moisture of dried product	Flavor	Color	Texture
p.s.i.g.	%			
50	4.5	3	2 (charred)	3 (gluey)
45	4.7	5	6	7
40	5.1	9	9	9
35	5.8	10	9	9

The data in Table 2 indicate that 40 p.s.i.g. is about the maximum steam pressure that can be employed without injuring the quality of the dried product.

Optimum time for dehydration: With juice the same as that in the experiments mentioned above and with a steam pressure of 40 p.s.i.g. in the rolls, a study was made of the optimum time for dehydration to bring the moisture content to a level between 5 and 6 percent without any injury to color, flavor, or texture. The results are shown in Table 3.

TABLE 3

Optimum time for dehydration

(Pressure of steam in rolls = 40 p.s.i.g.)

Speed of rolls	Moisture content of dried product	Flavor	Color	Texture
r.p.m.	%			
14	5.1	9	10	10
12	5.0	10—	10—	10—
10	5.0	9	10	10
8	4.95	6	9	7

From the results in Table 3 it will be observed that with 40 p.s.i.g. in the rolls the optimum time for dehydration of fresh date-tree juice is that represented by a speed of the rolls at 12 r.p.m. However, the speed of the rolls may be varied between 10 and 14 r.p.m. with little injury to the product.

Effect of pH of juice: It has been pointed out before that if the juice is stored for some time, its pH falls with deterioration in quality. Because of the nature of the collection and the difficulty of transport to the central stations, it is possible that most of the juice will not reach the dehydrating plant in the fresh state. Hence it was considered desirable to find out whether the pH of fresh date-tree juice (which gradually falls during storage) indicates the quality of the juice and its drying characteristics. For this purpose, juice was stored for different lengths of time at room temperature (23° C.) until its pH fell to the desired level. It was then dehydrated. The results are shown in Table 4.

TABLE 4

Effect of pH on drying characteristics of date-tree juice

Steam pressure inside rolls = 40 p.s.i.g.
Speed of rolls = 12 r.p.m.

pH	Moisture content of dried product	Flavor	Color	Texture
	%			
7.2	5.0	10—	10—	10—
7.0	5.2	9	10	10
6.8	5.7	3	4	2 (gluey)
6.6	5.9	1	0—	0—(gluey)

In the next series of experiments, juice having a pH lower than 7.2 was brought to pH 7.2 with sodium carbonate and was dried, with the following results (Table 5).

TABLE 5

Effect of adjusting pH with sodium carbonate

Original pH	pH adjusted to	Moisture content of dried product	Flavor	Color	Texture
		%			
7.2	7.2	5.0	10—	10—	10—
7.0	7.2	5.15	10—	10—	10—
6.8	7.2	5.2	9	10	9
6.6	7.2	5.5	8	6	6

It may be inferred from the results in Tables 4 and 5 that the pH of a sample of juice is a good indicator of its drying characteristics. This is, however, true for untreated juice only. The quality of the dried product of juice the pH of which has fallen below 7.2 will be markedly improved if its pH is adjusted to 7.2 with sodium carbonate. The influence of sodium carbonate, however, diminishes with decreasing pH, indicating that products like lactic acid and invert sugar, which are formed as the pH falls (due to microbiological action), may also influence the quality of the dried product.

Retention of vitamins: In dehydrating with drum driers, the juice is allowed to be in contact with the heated surface for only about 5 minutes, if the speed of the drums is 12 r.p.m. Under these conditions it is expected that the product will retain, to a large extent, the nutrients of the fresh juice, particularly thiamine and ascorbic acid. To determine whether this supposition is true, a comparison was made of the results obtained by the drum-drying method and the orthodox open-pan boiling method with respect to the retention of vitamins in the dried products. (a) A sample of fresh juice was dehydrated by being boiled in open pans in the laboratory to a moisture content of 5 percent, and the dried product was analyzed for vitamins. (b) Another sample of the same fresh juice was dried on the drum drier with a steam pressure in the rolls of 40 p.s.i.g. and a speed of the rolls of 12 r.p.m. The dried product was then analyzed. (c) The best sample of a dehydrated product of date-tree juice available in the market was procured and analyzed. The results are shown in Table 6.

TABLE 6

Vitamin contents of date-tree juices dried by different methods

Sample	Moisture content	Ascorbic acid [a]	Thiamine [a]
	%	*mg./100 gm.*	*mg./100 gm.*
Fresh juice	86.3	29.9	0.46
Drum-dried product	5.0	24.7	0.41
Open-pan product	5.35	8.2	0.11
Market product	9.1	trace	nil.

[a] Converted to the basis of 86.3% moisture.

Table 6 demonstrates clearly that by drying date-tree juice under proper conditions with a double drum drier, a product is obtained that is much superior in nutritive value to that obtained by the orthodox method of open-pan boiling.

Summary

(1) A rapid method of dehydrating date-tree juice with a double drum drier has been found.

(2) The optimum conditions for dehydration of fresh date-tree juice (pH 7.2) with this drier are:

(a) a steam pressure of 40 p.s.i.g. in the rolls
(b) speed of rolls at 12 r.p.m.
(c) thickness of film 0.032 inch.

(3) The pH of the untreated juice is a good indicator of its drying characteristics. Fresh juice having a pH of 7.2 will give the best dried product under the optimum conditions mentioned above. The quality of the dried product deteriorates with the decreasing pH of the juice.

(4) Adjusting the pH to 7.2 with sodium carbonate for a juice the pH of which is below that level, results in improvement of the quality of the dried product.

(5) The drum-dried product is much superior in nutritive value to that obtained by boiling in open pans.

Reduction of Post-Harvest Spoilage in Fresh Fruits and Vegetables Destined for Long Distance Shipment[a]

DEAN E. PRYOR

Research Department, Wallace & Tiernan Sales Corporation, Monrovia, California

(Received for publication, August 8, 1949)

(REVIEW PAPER)

Methods of reducing post-harvest spoilage of fresh fruits and vegetables are reviewed with particular emphasis on the use of sulfur dioxide to reduce decay in grapes; carbon dioxide to prolong storage life of apples; nitrogen trichloride for controlling decay in citrus and certain other fruits and vegetables; and the efficacy of using treated wraps, chemical washes, waxes and chemically treated ices.

According to Wiant and Bratley *(32)* carlots of produce arriving on the New York market average 2.1 percent decay for fruit and 3.8 percent decay for vegetables. These data were gathered from a total of about 118,000 inspections. Approximately 15 percent of the fresh fruits and vegetables shipped by rail to market in the United States arrive at New York City. In 1948, the return to growers of vegetables (excluding potatoes) in California was $276,459,000.[b] If the percentage decay given by Wiant and Bratley can be applied to shipments of California vegetables, the loss from spoilage in this one group of commodities alone amounted to several million dollars in 1948. The figures just given are based upon inspection of carloads on arrival and do not take into account the loss from decay in the hands of the wholesaler, retailer, and ultimate consumer. If it were possible to collect the complete data for decay loss, the figure would be almost astronomical.

As far as vegetable spoilage is concerned, bacteria are the most important causal factors. Generally these organisms fall in the bacterial soft rot group (*Erwinia* sp.). Fungi also cause considerable loss, but the taxonomy is more complicated. For example, about 20 different fungi have been reported as causing post-harvest decay in tomatoes *(26)*. Furthermore, these parasites differ greatly in their response on the host, to environment, to the various control measures, and in their mode of infection. Thus, we see that the problem of post-harvest spoilage is a very important one from the economic standpoint and a complicated one from the scientific standpoint. Workers in the United States Department of Agriculture, in the state experiment stations, and in commercial organizations have aided greatly in reducing these losses.

Since in a previous review of this subject by Pentzer *(24)* emphasis was placed upon the importance of proper refrigeration during storage and transportation, this very important phase of the problem will not be taken up. In this discussion, an attempt will be made to cover primarily the chemical processes which are now in commercial use or which have been used commercially in the past. To further restrict the paper, the topic of general sanitation will also be excluded. The complete literature on the subject is not cited, but the references given will serve as a guide to anyone desiring to delve more deeply into the problem.

Compared with the amount of work done on field fungicides and bactericides, relatively little work has been done in attempting to reduce post-harvest spoilage by chemical means. The two fields are quite distinct. In the first case, the germicide must withstand weathering and, therefore, must be relatively insoluble. In the second case, the chemical must be relatively soluble if applied as a wash. Horsfall *(12)* has defined three principles of disease control as protection, immunization, and therapy. The protective treatment involves the elimination of pathogens from the environment or from the plant before infection has actually occurred. Immunization does not concern us in this discussion. Therapy involves curing the plant after infection has occurred. In the case of field fungicides, the protective material is generally applied before the disease becomes rampant. Thus, the infectious bodies—spores in the case of fungi—fall onto a surface which is germicidal. With post-harvest treatment, however, the germicide must have the properties of reaching the organism after it has been deposited upon the surface of the host. Because of the possible deleterious effect in the human diet, it is generally not desirable to have the chemical penetrate the host tissue and act in a therapeutic manner. The inoculum potential is of great importance with both field and post-harvest germicides. In the case of the post-harvest problem, the inoculum potential is increased by the use of water, storage under unsanitary conditions, contamination from packing material, and numerous other factors. In addition, the physiological condition of the host is important. When a fruit or vegetable is harvested, it immediately begins to die. The speed at which it dies is influenced by pathogenic organisms, state of maturity, storage temperature and humidity, degree of injury, rate of respiration, etc.

Reaching the organism is one of the most difficult problems encountered by the investigators studying means of control of post-harvest decay. Results in our laboratory have indicated that gases are much more effective in contacting the pathogen than liquids, even though wetting agents may be included in the treating solutions. Unfortunately, the number of gases found to be effective is relatively small.

A good many diverse chemicals have been used for reducing post-harvest spoilage. Possibly the easiest way to group them is by their method of application to the product, such as gases or washes.

Gases

The ideal gas for control of spoilage in fresh produce should, of course, be toxic to the organisms causing

[a] Presented before the Ninth Annual I. F. T. Meeting, San Francisco, Calif., July 12, 1949.

[b] The author is indebted to the Western Growers Association, Los Angeles, Calif., for this figure.

decay and non-toxic to the product. This hypothetical gas should preferably leave no residue on the product; or, at least, any residue that is left should be non-toxic to man. In addition to not affecting the organoleptic properties of the fruit or vegetable, it should be safe to use by the workers. In order to adequately penetrate packed boxes, if the gas is to be applied in this manner, it should be very slightly soluble in water. If the gas is soluble in water or is very reactive, it tends to accumulate in or on the produce in the outer portion of the package. It should also be non-corrosive to mechanical equipment. So far as is known, no gas completely satisfies these requirements.

Carbon dioxide. Carbon dioxide has been used to a limited extent for controlling spoilage. The gas is artificially introduced into storage rooms or refrigerator cars either by sublimation from solid carbon dioxide or from cylinders of the gas. In some cases, carbon dioxide from respiration is allowed to accumulate, rather than being artificially introduced. The amount of gas required to effectively reduce spoilage from pathogenic organisms varies considerably for the different fruits and vegetables *(9, 13, 23, 28, 30)*. In refrigerator cars, it is apparently feasible to maintain a concentration of about 6 percent *(1, 8)*. Probably the greatest commercial use of carbon dioxide is for storage of apples and pears. It is also of considerable benefit on other deciduous fruits *(9, 23, 28)*. One shipper has used solid carbon dioxide in refrigerator cars for strawberries. Only enough dry ice is placed in the car to furnish the CO_2 and ordinary water ice is used for refrigeration. Usually, rather high concentrations of CO_2 are required to reduce decay. It has been pointed out that carbon dioxide atmospheres will not control decay after infection of the host has been accomplished *(30)*, and the use of the carbon dioxide process has certain other disadvantages. When the gas is employed in storage, it is usually of such concentration that workers should not enter the rooms without an outside source of oxygen. Another disadvantage of CO_2 is that the proper concentration for one variety of apples may not be optimum for another variety, making it necessary to have a number of small rooms or to use a sub-optimal concentration of gas.

Sulfur dioxide. Sulfur dioxide has been used for a good many years to reduce decay in grapes, primarily caused by *Botrytis* sp. *(14, 15, 33)*. The gas may be applied directly from cylinders, by burning sulfur, or by release from sodium acid sulfite. A standard commercial practice is to introduce a mixture of air and sulfur dioxide containing about 2 percent of the chemical. The gas is applied directly into refrigerator cars or into storage rooms. In gassing a refrigerator car, sulfur dioxide is introduced at the desired concentration and the car is left closed for half an hour or so. In cold storage, several gassings may be made, depending upon how long the grapes are held. Loss from spoilage is controlled fairly well by applications made every 10 days. Care must be taken to exhaust the storage rooms after gassing in order to avoid over-treatment. The temperature of the grapes and their maturity at the time of gassing influence the amount of gas absorbed. Thus the success of the treatment depends to a certain extent upon the skill of the operator in taking into account all the factors involved. The gas is very corrosive since upon contact with water it forms sulfurous acid, then gradually upon oxidation, sulfuric acid. According to Jacob *(14, 15)*, it is desirable to have 15 to 20 p.p.m. of sulfur dioxide in the berry of table grapes, and as much as 50 p.p.m. in wine grapes. A concentration of 20 p.p.m. does not seem to be detectable by taste, but 100 p.p.m. is apparent. The gas, of course, is quite soluble in water. Although no tests have been made, it is suspected that the outer grapes in a package or the outer packages of a carload may pick up more gas than those less accessible. Over-treatment may be evidenced as off-flavor or bleached spots on the berry.

Ozone. The use of ozone has been suggested from time to time as a means of controlling spoilage in fresh fruits and vegetables, and occasionally has been tried out commercially. According to newspaper reports, one of the most recent commercial trials is on Florida citrus. However, Klotz *(18)* showed that ozone was ineffective as far as citrus decay organisms are concerned.

Nitrogen trichloride. In 1927, Wallace and Tiernan, in cooperation with the California Fruit Growers Exchange, began to investigate the effect of nitrogen trichloride in controlling citrus decay. As a result of the preliminary work, L. J. Klotz of the California Citrus Experiment Station became interested in the process. He demonstrated that the gas could be used effectively in controlling blue and green mold *(18)* In 1934, the first commercial installation, under the name "Decco Process," was made. The gas, being very unstable, must be generated on the spot. Through continuous reaction and extraction by air, the compound never accumulates in the liquid state. The gas, diluted with air, is introduced into storage rooms or into refrigerator cars for a period sufficient to achieve adequate control. During the gassing period, concentration of the gas in the testing chamber is analyzed frequently and adjustments on the machine made as necessary. Both in storages and in refrigerator cars, forced air circulation must be provided. The gas is almost insoluble in water, and probably because of this property, seems to have the ability of penetrating packed boxes of produce fairly uniformly. It is somewhat lachrymatory and is poisonous in high concentrations; however, the concentrations used in treating are so irritating to the mucous membranes that a person is warned of its presence long before a dangerous concentration is achieved. One disadvantage of the gas is its corrosive effect on bare metal surfaces. This disadvantage, however, can be alleviated through the use of proper paints and equipment. Surprisingly enough, galvanized metals stand up very well under exposures to the gas. Many of the common paints will give adequate protection when properly applied.

Treatment of Some Fruits and Vegetables with Nitrogen Trichloride

Oranges. Oranges are generally treated in rooms used for coloring, precooling, or in refrigerator cars. In some cases, treatment is given at all of these places. Recent work by Littauer *(20)* has shown that a concentration of 7 mg. per cubic foot for 6 hours will satisfactorily control stem-end rot due to *Diplodia natalensis*

and decay due to *Penicillium digitatum* and *P. italicum*. Tests in our laboratory have indicated that within a refrigerator car a 4-hour exposure causes penetration of packed boxes of oranges sufficiently to reduce decay to a commercially important extent. Over-treatment by the gas may cause "etching" or pitting. The equipment, however, enables accurate concentration control and the phytotoxic level is relatively high so that injury rarely occurs under commercial conditions.

Lemons. In California, at least, lemons may be stored for a period as long as 6 months in insulated rooms held at about 58° F. (14.5° C.) and 85 to 88 percent relative humidity. As stated by Klotz *(18)*, lemons are very sensitive to the gas. Experimental work done under commercial conditions in 1941 indicated that blue and green mold could be satisfactorily controlled by frequent dosages at a very low concentration. At the present time, lemon storages are gassed from 3 to 7 times a week, depending upon the condition of the fruit and the prevalence of decay. Rooms are gassed at a concentration of 1 to 4 mg. per cubic foot for 4 hours. The treatment, of course, does not get deep-seated infections. After the storage period when the fruit is dumped for packing, it will be seen that treated lemons infected with *P. italicum* or *P. digitatum* have become mummified and brown while adjacent lemons are still healthy. In untreated storages, blue mold oftentimes will nest in crates until as much as 50 to 100 percent of the box is decayed.

Workers in Texas *(10, 27)* have shown that both blue and green mold and stem-end rot caused by *D. natalensis* are controlled by the gas under conditions found in the Rio Grande Valley. Biale *(3)* has shown that decaying lemons produce compounds which accelerate ripening of adjacent healthy lemons. It is well known also that ripe fruit tend to increase the rate of coloring in adjacent green fruit. This effect, which is probably due to volatile compounds, is reduced appreciably by the gassing treatment.

Cantaloupes. Cantaloupes are normally gassed in refrigerator cars during the precooling process. Barger and others *(1)* have shown that concentrations ranging from 11 to 25 mg. per cubic foot for 5 hours adequately reduce spoilage from the common fungi infecting cantaloupes after harvest. Recent experiments in our laboratory indicated that the gassing period can be reduced to 3 hours without affecting the degree of control obtained, provided the concentration is held within the range of 16 to 23 mg. per cubic foot, and provided also that the concentration in the car is brought up to the desired level within a short time. Commercially important control can be obtained with a gassing period of 2 hours. However, the control at 1 or 2 hours is not as good as that obtained at 3. In some cases, concentrations of 30 mg. per cubic foot, or higher, cause a slight browning of the sutures in mature melons and a fixing of the green color in less mature melons.

Tomatoes. Tomato decays due to *Rhizopus*, *Alternaria*, and other fungi causing post-harvest losses may be reduced satisfactorily using nitrogen trichloride for 4 hours at concentrations in the range of 5 to 12 mg. per cubic foot. Two gassing periods of 4 hours each on consecutive days gives better control of decay than one gassing period of 4 hours or 8 hours. Tomatoes have been treated with concentrations as high as 30 mg. per cubic foot. Over-treatment is evidenced by a sinking of the stem scar. Development of this symptom is influenced by the condition of the fruit as well as concentration of the gas. Even with very high concentrations, it has not been possible in the laboratory to produce pitting or etching of the skin except at wounds. When the fruit is affected by viruses, such as streak, which may cause blistering or tan to brownish patches on the immature fruit, gassing seems to accentuate these blemishes while the fruit is green. After the tomatoes have ripened, the discoloration very largely disappears.

Peppers. From the Decco treatment standpoint, peppers are handled similarly to tomatoes with one very important exception. Numerous tests have indicated that the gas has no appreciable effect on the surface of the pod; however, treatment above 4 mg. per cubic foot tends to cause slight bleaching of the stem which does not extend to the calyx. The first evidence of this bleaching is found at the broken end of the stem. Further increases in concentration above 4 to 5 mg. per cubic foot cause first, tannish streaking, and then, bleaching of all of the stem. Fortunately, this slight bleaching of the stem does not affect marketability.

Onions. Onions have not been treated commercially to any extent as yet, primarily because the producing areas have been different from those in which we are operating extensively. Laboratory and semi-commercial trials, however, indicate that decay due to *Botrytis* sp. and *Aspergillus niger* can be reduced significantly. In this connection, it is of interest to note that a concentration of 20 mg. per cubic foot applied weekly to stored onions did not give as good control as did 12 mg. per cubic foot for the same period, even though there were no macroscopically visible signs of injury.

Wraps

To be effective, chemicals used in treating wraps should possess many of the properties outlined previously for gases. The material should be odorless, or at least non-irritating. It should be toxic to the organisms and not to the host, and should have no effect on flavor. One serious difficulty with treated wraps is that it is hard to regulate the exposure to the volatile material emanated. This difficulty has been circumvented in some cases by using compounds which have vapor pressures at the temperatures employed, such that decay control is achieved below the phytotoxic concentration. Some success has been obtained in treating liners or shredded paper which is added to the packing container.

Oiled wraps. Oiled paper wraps or oiled shredded paper have been used for a good many years in controlling scald on apples and pears *(25)*. This does not come strictly under the scope of this paper since scald is a physiological disease resulting from the accumulation of injurious volatile products of host respiration.

Pine oil. A recent patent granted to MacRill and Baum *(22)* employs wraps treated with pine oil, a terpineol. It is stated that this treatment will satisfactorily control decay due to blue and green mold without affect-

ing flavor of the fruit. Taste tests indicated that flavor may actually be somewhat improved, or at least the flavor of the fresh orange is maintained for a longer period.

Diphenyl. Diphenyl impregnated wraps or paper liners *(11)* have been employed successfully in reducing decay in citrus. Apparently, workers object somewhat to the diphenyl odors and many taste tests have shown that diphenyl does affect flavor adversely. Feeding tests *(21)* have indicated that the compound is non-toxic to animals in the concentrations commonly employed.

Washes

Tests in our laboratory have shown that, in many cases, water alone seems to increase the incidence of decay. This may be due to physiological effect on the host, such as Johnson *(16)* has found with growing plants, or it may be due to the fact that water moves the infectious organisms to a favorable site. However, for the sake of cleanliness, water must be used in preparing many fruits and vegetables for market. Water or aqueous solutions of chemicals are necessary to remove fungicide and insecticide residues. In the case of sub-tropical crops where smudging is used to maintain temperature during cool periods, some means must be employed to remove the accumulated soot.

In the West, particularly, water is very valuable and economy must be practiced in its use. Furthermore, in some localities, sewage facilities are not adequate to take care of the waste water in a flow-through system. As a result, the water is recirculated in the wash tanks with the consequent build-up of plant pathogens. Where the water is refrigerated to cool the produce, the cost of refrigeration makes it imperative that the water be recirculated.

From the public health standpoint, washing with water is of considerable importance. Elrod *(5)* has shown that the IMVIC pattern for *Erwinis* sp. might tend to classify some of them as aberrant coliforms. Great quantities of animal excrement are used in the production of crops. This in itself would tend to build up the coliform count on produce. The edible portions of many fruits and vegetables are exposed to the hands of workers. The transmission of human diseases by having infected or contaminated workers packing produce which is not normally cooked would seem to be a possibility. The careful housewife, of course, tries to wash these products clean but she may not make them sterile as far as organisms are concerned.

Hot water. One of the oldest treatments in the citrus industry is hot water *(7)*. Although this is not strictly a chemical treatment, it is quite effective in reducing decay from certain organisms and may be combined with soda ash or borax. With oranges, the fruit is subjected to water at temperatures of 115° to 120° F. (46° to 49° C.) for 2 to 4 minutes. Hot water is most effective against brown rot, *Phytophthora citrophthora (2, 19)* and will reduce decay 30 hours after infection. Thus, it is a therapeutic treatment. Water at this temperature also reduces infections from other fungi during the washing operation. Freshly harvested fruit may be injured by such high temperatures. With lemons, it is often necessary to cure for a period of 2 to 5 days so that the high temperature will not rupture the oil glands or cause other damage to the tissue.

Soda ash. Sodium carbonate at a concentration of 1¼ percent by weight and sodium bicarbonate at 2½ to 3 percent by weight have been shown to effectively reduce brown rot and blue and green mold on citrus *(7, 19)*. The soda ash itself is helpful in cleaning the fruit. Treatment of the fruit with soda ash is also one of the oldest processes employed in the citrus industry and is often used in conjunction with cleaning materials in hot water.

Borax. A 4-minute submersion in 5 to 8 percent borax is used commercially to reduce decay from blue and green mold and from stem-end rot *(7, 34)*. Other boron compounds have also been employed with varying degrees of effectiveness. Fawcett *(7)* suggests that a proportion of 2 parts borax to 1 boric acid may be used at the percentages mentioned previously. One disadvantage of the borax treatment is that it is more effective against green mold, *P. digitatum*, than it is against blue mold, *P. italicum*. It has been noticed that, after green mold has been eliminated with the borax treatment, blut mold oftentimes becomes very serious. The blue mold organism is able to spread through a box of citrus by contact, while green mold usually attacks only through wounds.

Sulfur compounds. Sulfur compounds of various types have been used commercially for a good many years in treating produce after it is harvested. Fawcett *(7)* has pointed out that they are not effective on brown rot of citrus. These compounds may be used in the form of calcium magnesium sulfides, sulfur dioxide, or polysulfides. The fungicidal activity of sulfur and many compounds containing this material is well known. The effectiveness of these washes, however, is not well established. Tests in our laboratory indicate that some of them, at least, will not control bacterial soft rot. Aside from any benefit that these materials may have in reducing decay, they would seem to cut down the amount of brownish discoloration often occurring at wounds. Sulfiting to prevent discoloration has been used for a good many years in dehydrating or drying of fruits and vegetables.

Phenolics. Sodium chlororthophenylphenate *(6, 17)* has been used effectively to reduce blue and grey mold on apples and pears, these decays being caused respectively by *P. expansum* and *Botrytis* sp. When sodium silicate is used for spray residue removal, it is recommended that 1.2 percent of sodium chlororthophenylphenate be included. It has also been applied effectively as 0.4 percent solution in the rinse. On pears, better control is obtained with grey mold than with blue. Observations in a packing house in the Pacific Northwest indicated that the odor from this treatment is quite objectionable and many workers are sensitive to the chemical. The sensitivity is evident as a rash on the hands, arms, or face.

Hypochlorite. Sodium hypochlorite solutions are used quite extensively in the citrus industry. An attempt is made to hold the concentration at about 6000 p.p.m. of available chlorine. It has been found to be ineffective on lemons *(10, 27)*. Recent commercial trials on peaches *(4)* using a concentration of 120 p.p.m.

to 140 p.p.m. available chlorine in refrigerated water showed reduction of spoilage. The treatment is also used on tomatoes and asparagus. With this latter crop, difficulty has been experienced with objectionable odor where the chemical is applied to hydrocoolers.

Copper sulfate. This compound was used a number of years ago in the citrus industry to control brown rot and blue and green mold *(29)*. The recommended concentration was 1 to 2 pounds per 1000 gallons of water. Other more effective chemicals have now obviated its use in the industry *(7)*.

Potassium permanganate. Early in the development of the citrus industry, potassium permanganate was used at the rate of 1½ pounds per thousand gallons *(7)*. It was somewhat less effective even than copper sulfate and tended to emphasize the scars.

Miscellaneous chemicals. The quaternary ammonium compounds, formaldehyde, metaldehyde, and crotonaldehyde, have been used to a limited extent in treating produce after it is harvested. Little information is available as to the effectiveness of these chemicals on post-harvest decay.

Decco Process

The Wallace and Tiernan laboratory has been working for a number of years attempting to develop active chlorine washes for reducing decay in fruits and vegetables. Emphasis has been placed on this particular element because, after the disinfecting job is done, only the innocuous chloride ion remains. The activity of chlorine is influenced greatly by pH and by combination with various amines. It has been found that this biological activity is evident both on pathogens and on the host. Molecular chlorine, for example, is very effective in killing pathogenic organisms. It is also quite phytotoxic in solution. The problem then is to regulate the activity so that the organisms may be killed without injuring the host. This can be done in some cases by regulating pH and in others by suppressing the activity of the chlorine through chlorination of an amine.

Potatoes. It is well known that with decreasing pH the rate of bacterial kill is increased with a given concentration of chlorine. Experiments on potatoes have shown that this holds true in controlling decay. However, if the pH falls very low, injury to the host is likely to result; and although the treating solution may be more bactericidal, the net result is an increase in the amount of decay in potatoes. If the pH goes above 7, the rate of kill falls off rather rapidly until at pH 9.5, for example, the period required for kill is about 250 times as long as it is at pH 5. Continuous treatment with chlorine tends to increase acidity, while soil and refuse introduced into the washer decrease acidity. In order to maintain the pH at the optimum level, it is generally necessary to add acidic or basic materials. With high concentrations, or high pH, the skin tends to turn excessively dark after the initial bleaching action. Furthermore, on the skinned surfaces, a heavy scablike layer is produced which usually cracks. In addition to reducing decay, the treatment seems to increase the rate of suberin formation on the skinned surfaces. Furthermore, the treatment tends to brighten the potatoes and make them more attractive to the housewife.

Asparagus-Celery-Brussels Sprouts-Spinach. A new wash type process employing chlorine as the active ingredient is under extensive commercial trial at the present time on these crops. It has shown promise in reducing bacterial soft rot (*Erwinia* sp.) and pink rot (*Sclerotinia* sp.).

Ices

In some respects, ices containing chemicals are similar to treated washes. The problems of incorporating germicidal material, however, are more difficult. In freezing the blocks of ice, in order to have the treating material distributed throughout the block, a eutectic mixture must be obtained. This eutectic mixture may not be at the concentration desired for treatment. If the concentration is not correct, the chemicals may concentrate in the core. Unless the material has little toxicity to the host, the continued action due to the melting ice may bring about over-treatment. Furthermore, such treatment may leave objectionable residues unless the material is completely dissolved in the block. The meltage may flow through the load in channels; thus the produce may not be adequately covered by the germicide even though cooling may be obtained. Care must be taken that the chemical does not lower the freezing point to such an extent that the produce is injured. Commercially, many ice plants freeze ice for a good many purposes other than top or body icing of vegetables. At present, they do not view too favorably freezing treated ice for fear that they will be sending it out to the wrong customers. Several proprietary germicidal ices have been offered to the fruit and vegetable trade. Of the ones with which I am familiar, the active ingredients have been chloramine-T; sodium benzoate; quaternary compounds; and some aldehydes, such as metaldehyde and crotonaldehyde. As an alternative to freezing the material in the block of ice, one process adds the treating chemical at the crusher. This type of operation has a disadvantage in that the treating solution flows down over the material for a short while and then is washed off by the continued melting of the ice. If the germicide completely covers the product before it is too diluted, it may reduce decay; however, few technical data are available to substantiate its effectiveness one way or another.

Waxes

As a means of incorporating a germicide, waxes have seemed attractive to many investigators. The wax, of course, is applied to improve appearance and to reduce water loss from evaporation or transpiration. So far as is known to me, the waxes now on the market do not reduce the amount of decay sufficiently to be of commercial importance. They do unquestionably improve the appearance of many products and tend to cut down the loss of weight from evaporation.

LITERATURE CITED

1. Barger, W. R., Wiant, James S., Pentzer, W. T., Ryall, A. Lloyd, and Dewey, D. H. A comparison of fungicidal treatments for the control of decay in California cantaloupes. *Phytopathology* **38**, 1019 (1948).
2. Barrett, J. T., and Fawcett, H. S. Withertip, tear-stain, and control of brown rot. *California Citrograph* **7**, 232 (1922).
3. Biale, J. B., and Shepherd, A. D. Respiration of citrus fruits in relation to metabolism of fungi. I. Effects of

emanations of *Penicillium digitatum Sacc.* on lemons. *Am. J. Botany* **28**, 263 (1941).

4. CARDINELL, H. A., AND SMITH, MAX. Peach rot tests with the "stericooler." *Mich. State Hort. Soc., Ann. Report* **103** (1947).
5. ELROD, R. D. The *Erwinia*-coliform relationship. *J. Bact.* **44**, 433 (1942).
6. ENGLISH, HARLEY, WRIGHT, T. R., AND SMITH, EDWIN. Chemicals cut storage losses. *Better Fruit* **43**, No. 2, 9 (1948).
7. FAWCETT, HOWARD S. *Citrus Diseases and Their Control.* 2nd Ed. 1936, McGraw-Hill Book Co., New York.
8. GERHARDT, FISK. A study of CO_2 gas retention in refrigerattor cars during the commercial freight shipment of sweet cherries. *H. T. & S. Office Rpt.* **75**, *U. S. Dept. Agr., Bur. Plant Ind., Soils and Agr. Engin.* (1941).
9. ———, and RYALL, A. LLOYD. The storage of sweet cherries as influenced by carbon dioxide and volatile fungicides. *U. S. Dept. Agr. Tech. Bull.* **631** (1939).
10. GODFREY, G. H., AND RYALL, A. L. The control of transit and storage decays in Texas lemons. *Texas Agr. Exp. Sta. Bull.* **701** (1948).
11. HOPKINS, E. F., AND LOUCKS, K. W. The use of diphenyl in the control of stem-end rot and mold in citrus fruits. *Citrus Industry* **28**, No. 10, 5 (1947).
12. HORSFALL, JAMES G. Fungicides and their action. *Annales Cryptogamici et Phytopathologici* **2**, 1 (1945).
13. HUKILL, W. V., AND SMITH, EDWIN. Cold storage for apples and pears. *U. S. Dept. Agr. Circ.* **740** (1946).
14. JACOB, H. E. Grape growing in California. *Calif. Agr. Ext. Serv. Circ.* **116** (1947).
15. ———. The use of sulfur dioxide in shipping grapes. *Calif. Agr. Exp. Sta. Bull.* **471** (1929).
16. JOHNSON, JAMES. Water-congestion in plants in relation to disease. *Wisc. Agr. Exp. Sta. Res. Bull.* **160** (1947).
17. KIENHOLZ, J. R. Chemicals aid Hood River pears. *Better Fruit* **43**, No. 2, 18 (1948).
18. KLOTZ, L. J. Nitrogen trichloride and other gases as fungicides. *Hilgardia* **10**, 27 (1936).
19. ———, FAWCETT, H. S., AND HUILLIER, L. L. Laboratory experiments on the control of brown rot of lemons (Abs.) *Phytopathology* **24**, 1140 (1934).
20. LITTAUER, F. Control of Diplodia stem-end rot and molds in Shamouti oranges with nitrogen trichloride (Decco Process) *Palestine J. Botany* **6**, 205 (1947).
21. MACINTOSH, F. G. The toxicity of diphenyl and 0-phenylphenol. *Analyst* **70**, 334 (1945).
22. MACRILL, JOHN R., AND BAUM, ROBERT A. Citrus Wrapper (to Fernstrom Paper Mills, Inc.) U. S. Patent 2,443,795 (June 22, 1948).
23. O'REILLY, H. J. Peach storage in modified atmospheres. *Proc. Amer. Soc. Hort. Sci.* **49**, 99 (1947).
24. PENTZER, W. J. Handling and storage of fruits and vegetables for processing. *Food Technology* **1**, 565 (1947).
25. POWELL, G. H., AND FULTON, S. H. The apple in cold storage. *U. S. Dept. Agr. Bur. Pl. Ind. Bull.* **48** (1903).
26. RAMSEY, GLEN B., AND LINK, GEORGE K. K. Market diseases of fruits and vegetables: Tomatoes, peppers, eggplants. *U. S. Dept. Agr. Misc. Publ.* **121** (1932).
27. RYALL, A. LLOYD, AND GODFREY, G. H. Dip and gas treatments for the reduction of post-harvest decay in Texas lemons. *Phytopathology* **38**, 1014 (1948).
28. SHUTAK, VLADIMIR, AND CHRISTOPHER, E. P. Prolonging shelf life of plums with carbon dioxide. *Proc. Amer. Soc. Hort. Sci.* **51**, 231 (1948).
29. SMITH, R. E., RAMSEY, H. J., SMITH, E. H., BABCOCK, E. B., AND SMITH, C. O. The brown rot of the lemon. *Calif. Agr. Exp. Sta. Bull.* **190** (1907).
30. SMOCK, R. M. Some requirements of McIntosh apples in controlled atmosphere storage. *Proc. Amer. Soc. Hort. Sci.* **50**, 109 (1947).
31. ———, AND SOUTHWICK, F. W. Air purification in the apple storage. *Cornell University Agr. Exp. Sta. Bull.* **843** (1948).
32. WIANT, JAMES S., AND BRATLEY, C. O. Spoilage of fresh fruits and vegetables in rail shipments unloaded at New York City. *U. S. Dept. Agr. Circ.* **773** (1948).
33. WINKLER, A. J., AND JACOB, H. E. The utilization of sulfur dioxide in the marketing of grapes. *Hilgardia* **1**, 107 (1925).
34. WINSTON, J. R. Reducing decay in citrus fruit with borax. *U. S. Dept. Agr. Tech. Bull.* **488** (1935).

AMINO ACID COMPOSITION OF FISHERY PRODUCTS

Abstract by Maurice E. Stansby of the Fishery Technological Laboratory, Fish and Wildlife Service, Seattle, Washington.

Article by Catherine P. Deas and H. L. A. Tarr (Pacific Fisheries Experimental Station, Vancouver, B. C.), published in *Journal of the Fisheries Research Board of Canada* **7**, 9, 513 (1949).

The following products were analyzed microbiologically (method of Stokes et al.) after enzymic hydrolysis: red cod flesh, sockeye salmon flesh, herring flesh, dogfish liver waste water, and black cod waste water. The following products were analyzed similarly after acid or alkali hydrolysis: herring milt, white spring salmon milt, chum salmon milt, herring roe, white spring salmon roe, herring meal, herring stickwater, red cod flesh, herring flesh, and myosin. The table shows a few selected results obtained in the alkali and acid hydrolysis series. Values are expressed as grams of amino acid per 16 grams of nitrogen.

Enzyme hydrolysis gave lower values for lysine, arginine, histidine, and phenylalanine when hydrolyzed with enzymes than for acid hydrolysis. The reverse was true for methionine, valine, isoleucine, and leucine. Alkaline hydrolysis gave lower values for tyrosine and tryptophane than did enzyme hydrolysis.

Material hydrolyzed	Arginine	Histidine	Isoleucine	Leucine	Lysine	Methionine	Phenylalanine	Threonine	Valine	Tryptophane	Tyrosine
Herring milt	13.5	0.6	3.1	5.0	1.5	0.9	2.3	2.7	3.1	0.37	0.14
Herring roe	4.8	1.2	7.7	11.3	1.8	1.8	4.8	5.9	6.5	1.1	3.2
Herring flesh	5.9	2.0	6.4	8.0	8.2	2.2	4.5	4.5	5.1	0.7	2.2
Herring meal	*	0.61	6.6	10.1	4.4	2.7	4.4	4.4	5.7	1.0	3.2
Herring stickwater	3.7	0.5	1.6	3.9	4.1	0.7	1.8	2.2	2.1	1.3	4.1
White spring salmon milt	11.1	0.46	3.2	5.6	1.8	0.92	2.3	2.4	3.3	0.35	1.5
Chum salmon milt	11.9	0.7	3.5	5.7	2.1	1.1	2.4	2.4	3.3	0.32	0.81
White spring salmon roe	5.9	1.4	8.2	11.1	1.8	1.9	6.3	4.7	7.5	0.7	3.0
Red cod flesh	4.3	1.6	6.8	11.4	14.4	2.6	4.4	5.1	5.0	0.1	0.4

*Consistent arginine values for herring meal could not be obtained.

Commercial Fisheries Abstracts, January 1950.

Peroxidase Activity of Apple Tissue[a]

R. RAMAMURTI REDDI,[b] W. B. ESSELEN, JR., AND C. R. FELLERS
Department of Food Technology, University of Massachusetts, Amherst, Massachusetts[c]

(Received for publication, September 27, 1949)

The peroxidase activity of apple tissue was measured with three different substrates: (1) o-phenylenediamine, (2) pyrogallol, and (3) guaiacol. The behavior of the enzyme was not the same with the substrates studied. Data on the effect of temperature and hydrogen peroxide, sulfur dioxide, ascorbic acid, sodium chloride, dextrose, sucrose, thiourea, allylthio urea and glutothione on peroxidase activity are presented.

Peroxidase destruction is widely used as an indicator of enzyme destruction in food processing. It has also been suggested that it may play some role in enzymic deterioration of foods, such as off-flavor production. It was the object of this investigation to study the peroxidase activity of apple tissue with three substrates; namely, guaiacol, o-phenylenediamine, and pyrogallol and to see if there were any differences in behavior towards these substrates.

Onslow *(7, 8, 9)* found that apple fruit contained an oxidase and gave an explanation for the darkening of freshly cut apple surface. Overholser and Cruess *(10)* made an extensive investigation of the oxidase system of apples and considered the oxidase system as consisting of peroxidase and an organic peroxide. Drain *(3)* reported that oxidase activity was rather closely localized in the fruit of many apple varieties. Balls and Hale *(1)* came to the conclusion that darkening of freshly cut apple surface was a reaction catalyzed by peroxidase. Ponting and Joslyn *(11)* stated that it was polyphenolase and not peroxidase that was chiefly responsible for the darkening of freshly cut apple surface.

Schwimmer *(12)* gave evidence to show that different vegetables contain more than one peroxidase and that varieties vary in their activities towards iodide and pyrogallol. Joslyn *(5)* pointed out that the relative activity of the peroxidases of a particular vegetable tissue varies with the indicator.

Experimental

Throughout these investigations McIntosh apples that were frozen at —17.8° C. (0° F.) as soon as they were picked, were used. The apple tissue was obtained by peeling and coring the apple in the frozen state. The buffer employed in all the experiments was made of 0.2 molar disodium hydrogen phosphate and 0.1 molar citric acid.

Preparation of an Extract from Apple Tissue for Peroxidase Studies

One hundred grams of frozen apple tissue were blended in a Waring Blendor with 200 ml. of cold acetone at 0° C. (32° F.) for five minutes and immediately filtered under suction. The residue was again blended for three minutes with 100 ml. of cold acetone at 0° C. (32° F.) and filtered under suction. This process was repeated once again and the final residue was extracted for one hour with 100 ml. phosphate-citrate buffer and with continuous agitation. The suspension was centrifuged and the supernatant liquid was treated with three times its volume of 90 percent ethyl alcohol. It was then centrifuged and the residue was suspended in a minimum amount of cold distilled water. The suspension was again precipitated in a similar manner and the residue resuspended in a minimum amount of distilled water, after which it was filtered through a celite filter aid. The clear filtrate exhibited strong peroxidase activity but showed no polyphenolase activity with catechol. It was almost colorless and to a large extent free from tannins, sugars, organic acids and other water soluble material. This extract, referred to as "the enzyme extract," was used for studies on peroxidase activity of apple tissue. The enzyme extract was always stored at 0° C. (32° F.) when not in use.

Methods of Measurement of Peroxidase Activity

Guaiacol-Peroxidase Activity: The method used was to a large extent adapted from that of Hussein and Cruess *(4)*. To 1 ml. of a suitable dilution of the enzyme extract were added 2 ml. phosphate-citrate buffer at pH 5.5 and enough distilled water to make the total volume 15 ml. when all the reagents were added. One ml. of 0.3 percent hydrogen peroxide solution (Merck Superoxol) was added to this mixture in an Evelyn tube (Macro type used in Evelyn Photoelectric Colorimeter) and the tube was placed in a water bath 25° C. (77° F.). After allowing five minutes for the reaction mixture to attain the temperature of the water bath, 1 ml. of 1 percent alcoholic solution of guaiacol was added and the reaction was allowed to proceed for 45 minutes. The Evelyn tube was then taken out of the water bath and the outside wiped clean. The optical density of the solution was measured 45 to 50 minutes after the addition of guaiacol, in an Evelyn Photoelectric Colorimeter with filter No. 420 and with the blank adjusted for 100 percent transmission. The blank was prepared under the same conditions except that the enzyme extract was boiled for five minutes, cooled, and made up to original volume. The activity was expressed as optical density.

No attempt was made to arrest the reaction since it was found convenient to make the measurements between 45 and 50 minutes after the start of the reaction, during which period the maximum optical density attained remained constant.

O-phenylenediamine-Peroxidase Activity: The following method based on the use of o-phenylenediamine proved to be very satisfactory. To 1 ml. of a suitable

[a] Presented before the Ninth Annual I. F. T. Meeting, San Francisco, July 13, 1949.

[b] Present address: Ramanapalli (Post), Cuddapah, Madras Province, India.

[c] Contribution No. 728 Massachusetts Agricultural Experiment Station, Amherst.

dilution of the enzyme extract in a 125 ml. Erlenmeyer flask were added 2 ml. of phosphate-citrate buffer at pH 5.1 and enough distilled water to make a final volume of 15 ml. when all the reagents were added. To this 1 ml. of 0.3 percent hydrogen peroxide solution was added and the flask was placed in a water bath at 25° C. (77° F.) for five minutes. One ml. of 1 percent aqueous solution of o-phenylenediamine dihydrochloride (Eastman Kodak Co.) whose pH had been adjusted to 5.1 with sodium hydroxide, was then added to this mixture by means of a rapid flowing pipette noting the time of half delivery. After exactly five minutes, 2 ml. of saturated solution of sodium bisulfite (Merck Reagent) were added to this mixture in order to arrest the reaction. The mixture was extracted with small quantities of ethyl acetate [4] until all the color was extracted and the extracts were filtered through Whatman No. 4 filter paper after wetting it with ethyl acetate. The combined extracts were made up to 25 ml. with ethyl acetate and the optical density was measured in an Evelyn Photoelectric Colorimeter using filter No. 420. The colorimeter was adjusted for 100 percent transmission with a blank prepared with a heat inactivated enzyme extract. The scale of the galvanometer was calibrated in mg. of potassium dichromate in 100 ml. of aqueous solution with filter No. 420 and with the colorimeter adjusted for 100 percent transmission with distilled water. The enzyme activity was expressed as dichromate equivalents. One dichromate equivalent of enzyme activity is defined as the activity that produces a color intensity, under the above experimental conditions, equal to that of 1 mg. of potassium dichromate in 100 ml. of aqueous solution when measured at a wave length of 420 millimicrons.

In measuring the activity of clear enzyme preparations, direct measurements of the color intensity of the reaction mixture after the addition of a saturated solution of sodium bisulfite can be made without extraction by carrying out the reaction in an Evelyn tube with a proper blank. In all these experiments ethyl acetate extraction was employed, except where otherwise stated. The following precautions must be taken in using this method. With the apple tissue the optimum activity was obtained at pH 5.1. With other material the reaction should be carried out at the optimum pH for that material. The 1 percent aqueous solution of o-phenylenediamine must be prepared every five hours as precipitation occurs after that period. It is advisable to let the ethyl acetate extracts stand for ten minutes before the optical density measurements are made, to allow the minute droplets of water, if any, to settle down. This method was found to give reproducible results.

Pyrogallol-Peroxidase Activity: The method used for measuring the activity was essentially the same as that described by Sumner and Gjessing *(13)*. To 1 ml. of proper dilution of the enzyme extract were added 2 ml. of phosphate-citrate buffer at pH 6.5 and enough distilled water to make the total vloume 15 ml. when all the reagents were added. (It was found necessary to use four to five times the concentration of the enzyme extract to obtain measurable optical densities for pyrogallol-peroxidase measurements that were used for either guaiacol or o-phenylenediamine peroxidase activities.) One ml. of 0.3 percent hydrogen peroxide solution was added to this mixture in a 125-ml. Erlenmeyer flask. The flask was then placed in a water bath, at 25° C. (77° F.) for five minutes. One ml. of 1 percent pure pyrogallol (Eastman Kodak Co.) solution was added by means of a rapid flowing pipette noting time of half delivery. After exactly five minutes the reaction was arrested by the addition of 2 ml. of glacial acetic acid. The mixture was extracted with pure diethyl ether in small quantities until all the purpurogallin was removed. The combined ether extracts were filtered through a Whatman No. 4 filter paper after wetting it with ether. The filter paper was washed with a little ether and the total ether extracts together with the washings were made up to 25 ml. with ether. The optical density was measured in an Evelyn Photoelectric Colorimeter, with filter No. 420 and with the colorimeter adjusted for 100 percent transmission with a blank prepared with heat inactivated enzyme extract. The scale of the galvanometer was calibrated in mg. of pure purpurogallin per 25 ml. of ether. The enzyme activity was expressed as mg. of purpurogallin per 25 ml. It was found best to prepare the pyrogallol solution every day and store it at 0° C. (32° F.) when not in use.

Relative Sensitivity of Guaiacol, O-phenylenediamine and Pyrogallol Reactions to Colorimetric Measurements: The relative sensitivity of the peroxidase activity on the three substrates, to colorimetric measurements was determined. The experiments were performed under standardized conditions and the activities were measured at different time intervals. In the measurement of guaiacol-peroxidase activity 2 ml. of distilled water were added just before the colorimetric measurement so that the total volume of the reaction mixture was 17 ml. in all cases, for the purpose of comparison. The activities with o-phenylenediamine and pyrogallol as substrates were measured both by direct colorimetric measurement of the 17 ml. of the reaction mixtures and by measurement of their ether extracts in the usual way.

With the three substrates used, the peroxidase activity was most sensitive to colorimetric measurements with o-phenylenediamine as substrate while pyrogallol was the least sensitive substrate.

The Effect of Time on Peroxidase Activity: The activity of the enzyme extract was measured at various time intervals. Three different samples of enzyme extract were used with the different substrates. In the case of guaiacol the effect of time was observed at different pH levels (3.5, 4.0, 4.5, 5.0 and 5.5). The greatest degree of activity was observed at pH 5.5. At all levels the activity reached the maximum after 45 minutes, remained stationary for a period of at least 10 minutes, and then tended to decrease. The course of the reaction was similar at all the pH values. With

[4] Wallerstein et al. *(14)* used ethyl acetate for extracting the color due to the oxidation of o-phenylenediamine. In the present method ethyl acetate also was found to be well suited for the purpose.

TABLE 1

Effect of Hydrogen Peroxide Concentration on Peroxidase Activity

	Percent activity with different concentrations of hydrogen peroxide in mols. per liter									
	1.5×10^{-3}	2.9×10^{-3}	5.9×10^{-3}	1.2×10^{-2}	1.5×10^{-2}	1.8×10^{-2}	2.4×10^{-2}	2.9×10^{-2}	4.1×10^{-2}	5.9×10^{-2}
Guaiacol-peroxidase			100	33.9		27.9	15.4	0		
O-phenylenediamine-peroxidase	77.2	93.6	100		83.5		74.9	68.6	58.1	44.2
Pyrogallol-peroxidase	100	100	100	100		78.9		68.4		

o-phenylenediamine as substrate the course of the reaction followed a straight line for the first 11 minutes, which showed that the activity can be measured safely during that period. With pyrogallol as a substrate the course of the reaction followed a straight line for the first 10 minutes and then the curve began to flatten off.

The Effect of pH on Peroxidase Activity: The effect of pH was observed with the three substrates (three different samples of the enzyme extract were used with three different substrates). With a guaiacol substrate the maximum activity was exterted at a pH range of 5 to 6, with a peak at 5.5; with o-phenylenediamine the maximum activity was exerted at a pH range of 4.9 to 5.4 with a peak at 5.1; and with pyrogallol the maximum activity was exerted at pH 7.

Inhibition of Peroxidase Activity [e]

Effect of Hydrogen Peroxide: It is often reported in the literature that hydrogen peroxide in higher concentrations inhibits peroxidase activity. Thus Hussein and Cruess *(4)* reported that for grape peroxidase, hydrogen peroxide concentrations much above 5×10^{-4} mols. per liter materially decreased the rate of oxidation.

The peroxidase activity of the enzyme extract was measured with varying concentrations of hydrogen peroxide in the usual manner as shown in Table 1. Whereas at a concentration of 2.9×10^{-2} mols. per liter of hydrogen peroxide guaiacol-peroxidase activity was completely inhibited, the activities of both pyrogallol and o-phenylenediamine peroxidases still persisted. There was a progressive decrease in the activities with all the three substrates as the hydrogen peroxide concentration was increased.

Effect of Sulfur Dioxide: Aqueous solutions of sodium bisulfite to give various concentrations of sulfur dioxide were added to the reaction mixtures after all the other reagents, followed immediately by the addition of the substrate. The activity was measured in the usual way with the three substrates, except that with guaiacol as substrate, the optical density measurements were made exactly 45 minutes after the start of the reaction. The pH of the reaction mixtures in duplicate samples were also measured. The results are presented in Tables 2 and 3.

With the guaiacol substrate the activity had a negligible drop at initial concentrations of 0 to 100 p.p.m. of sulfur dioxide, steadily increased up to concentrations of 350 p.p.m. and then began to drop rather abruptly at that concentration until it completely ceased at 440 p.p.m. The latter concentration of sulfur dioxide is referred to as the extinction point. Hussein and Cruess *(4)* reported a progressive decrease in peroxidase activity with increasing concentrations of sulfur dioxide with grape peroxidase but did not observe any stimulation of the activity. The further addition of up to 10 ml. of enzyme extract at the extinction point did not restore the activity. However, addition of more hydrogen peroxide solution resulted in the reappearance of the activity. The activity returned even with 0.1 ml. of 0.3 percent additional hydrogen peroxide solution, reaching a maximum with 0.25 ml. and showing a decline thereafter until it completely disappeared once again with 4 ml. additional hydrogen peroxide solution. In experiments with guaiacol as a substrate, the maximum optical density was not obtained 45 minutes after the start of the reaction. Instead, the optical density continued to increase up to from 190 to 240 minutes, indicating that the activity still persisted. This observation was made with concentrations of 200 to 430 p.p.m. of sulfur dioxide. However, at a sulfur dioxide concentration of 440 p.p.m. activity once completely inhibited, never returned, even after 270 minutes.

TABLE 2

Effect of Sulfur Dioxide on Guaiacol, O-phenylenediamine, and Pyrogallol Peroxidase Activity

Sulfur dioxide conc. (p.p.m.)	Guaiacol		O-phenylenediamine		Pyrogallol	
	percent activity	pH	percent activity	pH	percent activity	pH
0	100.0	5.6	100	5.1	100	6.5
20	99.3	5.6	90	5.1	100	
100	94.0	5.5	76	5.0	95	
200	159.2	5.5	....	....	85	
250	172.9	5.4	50	4.9	75	
300	198.4	5.3	33	4.7	72	
350	209.2	5.1	....	....	68	
360	183.4	5.1	....	....	....	
380	172.9	5.0	....	....	....	
400	163.6	4.9	10	4.5	55	
410	159.2	4.9	....	....	....	
420	125.6	4.8	....	....	....	
430	78.9	4.8	....	....	....	
440	0.0	4.8	0	4.4	0	5.9

TABLE 3

Effect of Additional Hydrogen Peroxide at the Extinction Point on Guaiacol, O-phenylenediamine, and Pyrogallol Peroxidase Activity[a]

Ml. of 0.3% hydrogen peroxide added	Guaiacol Percent activity	O-phenylenediamine Percent activity	Pyrogallol Percent activity
0.1	82.0	....	....
0.25	136.9	52	72
0.5	111.9	64	72
0.75	91.0	78	72
1.0	73.6	84	....
3.4	57.6	....	....
4.0	0.0	....	....

[a] 440 p.p.m. Sulfur dioxide present at extinction point.

[e] For each inhibiting agent in all the experiments under this heading the same enzyme extract was used with the three different substrates. It was found necessary in the case of pyrogallol as substrate to use four times the concentration of the enzyme extract that was used for the other two, to obtain measurable optical densities. The original activity was always expressed at 100 percent activity.

The results with the o-phenylenediamine substrate show a progressive decrease in enzyme activity with increasing concentrations of sulfur dioxide, until it became completely extinct at a concentration of 440 p.p.m. of sulfur dioxide. The addition of more enzyme extract up to 10 ml. did not restore the activity at the extinction point. The addition of more 0.3 percent hydrogen peroxide at the extinction point, however, resulted in the reappearance of the activity.

The results with the pyrogallol substrate indicate a progressive decrease in enzyme activity with increasing concentrations of sulfur dioxide, until the activity becomes extinct at a concentration of 440 p.p.m. of sulfur dioxide. Addition of more enzyme extract at the extinction point up to 10 ml. did not restore the activity. The addition of more 0.3 percent hydrogen peroxide at the extinction point resulted in the reappearance of the activity.

It has been suggested that sulfur dioxide may act as an inhibiting agent in the following ways: (1) by reducing the pH of the reaction mixture, (2) by acting as a preferential substrate, and (3) by complex formation with the enzyme and thus directly inhibiting it. The possibility of inactivation due to the first may be eliminated because under the experimental conditions the drop in pH was not significant in relation to the inhibition of the activity. The second possibility of inhibition due to preferential substrate action does not appear plausible because of the complete absence of any delay or lag period for the appearance of the activity. The third possibility of direct action on the enzyme is ruled out when one considers that additional enzyme extract does not restore the activity once it has been completely inhibited. Further support is lent to this conclusion in view of the observation made by Cruess and Fong *(2)* that sulfur dioxide treated apricot slices, when washed in flowing water, exhibited the peroxidase activity once again. In view of the above considerations it is concluded that the inhibiting action of sulfur dioxide is due neither to preferential substrate action nor to complex formation. It is conceivable that relative concentrations of hydrogen peroxide and sulfur dioxide are contributing to the inhibiting effect. The fact that the activity with all the three substrates is completely inhibited at the same ratio of concentration of sulfur dioxide to hydrogen peroxide, and that further addition of hydrogen peroxide and not enzyme extract restores the activity, are compatible with such an hypothesis. The stimulating effect with guaiacol seems to be peculiar in view of the fact that no such effect was noticed with the other two substrates. It would appear that there is an optimum ratio of concentration of sulfur dioxide to hydrogen peroxide, where the maximum stimulating effect is obtained, when it is considered that even after complete inhibition, the stimulating effect is observed when hydrogen peroxide is added. The fact that maximum activity with guaiacol is obtained well beyond the normal 45 minute period is also significant in view of is peculiar behavior as substrate.

Effect of Ascorbic Acid: The peroxidase activity was measured with the three substrates in the presence of different concentrations of ascorbic acid in the usual manner, except that the hydrogen peroxide solution was added last to prevent the oxidation of ascorbic acid before the addition of the substrate. The results are shown in Table 4. With all the substrates, ascorbic acid delayed the appearance of activity for varying intervals of time depending on the concentrations used. The enzyme activity on the substrate after the delayed appearance, decreased with increasing concentrations of ascorbic acid (presumably due to the progressive inactivation of the enzyme through its action on the ascorbic acid). With increasing concentrations of the enzyme extract, the lag period after which the enzyme activity appears, for the same concentration of ascorbic acid, decreases. The results indicate that the ascorbic acid inhibition is due to its preferential substrate action.

TABLE 4

Effect of Ascorbic Acid on Peroxidase Activity

	Time in minutes before the appearance of activity with different concentrations of ascorbic acid expressed in p.p.m.											
	0	2	4	6	8	10	20	30	40	60	120	200
Guaiacol-peroxidase	1	10	20	35	60	80						
O-phenyl-enediamine-peroxidase	0			2		2.5	4	6	8	10	15	20
Pyrogallol-peroxidase	0		1.5			3	9	18	27			

Effect of Dextrose and Sucrose: Measurements of peroxidase activity in the presence of different concentrations of dextrose or sucrose were made with the three substrates, in the usual manner. With o-phenylenediamine as substrate, it became extremely difficult to extract the color with ethyl acetate with a dextrose or sucrose concentration of 20 percent or greater. Hence, direct measurements were made on the 17 ml. of the reaction mixture after the addition of sodium bisulfite in the usual manner. The results presented in Table 5 show that the enzyme activity decreased with

TABLE 5

Effect of Concentration of Dextrose and Sucrose on Peroxidase Activity

	Percent activity with different concentrations of sugar									
	0%	5%	10%	15%	20%	25%	30%	35%	40%	50%
	Dextrose									
Guaiacol peroxidase	100.0	91.8	84.5	77.0	72.1	67.4	60.3	49.8	—	—
O-phenylenediamine peroxidase	100.0	79.2	58.3	36.7	17.5	7.9	4.9	0.0	—	—
Pyrogallol peroxidase	100.0	76.5	65.9	54.5	45.4	36.4	18.2	0.0	—	—
	Sucrose									
Guaiacol peroxidase	100.0	92.5	88.9	—	81.9	—	69.0	—	62.4	52.7
O-phenylenediamine peroxidase	100.0	79.7	70.7	—	58.6	—	48.9	—	37.6	31.6
Pyrogallol peroxidase	100.0	83.3	76.2	—	54.8	—	47.6	—	40.5	28.6

increasing concentrations of dextrose. Whereas the enzyme activity was completely inhibited with both o-phenylenediamine and pyrogallol as substrates at a concentration of 35 percent dextrose, the activity with guaiacol as substrate still persisted. It may be seen that with sucrose there was a progressive decrease in activity with increasing concentrations. The activity with guaiacol as substrate was inhibited to a lesser degree than with either o-phenylenediamine or pyrogallol as substrates.

Effect of Sodium Chloride: It was observed that there was some degree of interference which may be attributed to liberation of chlorine from sodium chloride especially at higher concentrations, and prolonged periods as in the case of measurement of the enzyme activity with guaiacol as substrate. But the activity with the three substrates could be measured without any undue difficulty provided proper controls were carried out. At higher concentrations of sodium chloride a slight precipitation occurred in the extract. However, its interference with the progress of the enzyme action could be minimized by keeping the reaction mixture continuously agitated. It was observed that up to concentrations of 13 percent, sodium chloride had a slight stimulating effect on the activity with guaiacol and pyrogallol as substrates and a negligible inhibiting effect with o-phenylenediamine as substrate.

Effect of Thiourea and Allyl Thiourea: The experiments to study the effect of these two compounds were performed in the usual manner, except with o-phenylenediamine as a substrate where the addition of a saturated solution of sodium bisulfite resulted in a color change. This necessitated the measurement of the optical density after exactly five minutes without arresting the reaction. There was a progressive decrease in activity with increasing concentrations in both the cases but the extent of inhibition was different with each substrate and inhibiting agent. There was no lag period noticed in the appearance of the enzyme activity in any case. With guaiacol as substrate the maximum activity was reached after the normal 45 minute period. Additional hydrogen peroxide at the extinction point did not restore the activity, but additional enzyme extract did, in all the cases. The inhibition seems to be due to direct action on the enzyme.

Effect of Glutathione: Whereas the activity with guaiacol as substrate was completely inhibited at a concentration of 10 p.p.m. of glutathione, the activity still persisted with both o-phenylenediamine and pyrogallol as substrates though to a slightly different degree in each case. There was no lag period noticed in the appearance of the enzyme activity and it is concluded that the inhibition was due to direct action on the enzyme.

Effect of Temperature on Peroxidase Activity: The effect of temperature on the activity of the enzyme[1] was studied at temperatures ranging from 3° C. to 80° C. (37.4° F. to 176° F.). It was found that, with pyrogallol and o-phenylenediamine, the rate of oxidation even without the enzyme was increased at elevated temperatures. Hence, the reaction mixtures without the substrate and the enzyme were always brought to the temperature investigated and the substrate immediately followed by the enzyme extract was then added. Thus, non-enzymatic oxidation was minimized and enzyme destruction avoided, until the start of the reaction. The temperature of the reaction mixture was noted at the start and the termination of the reaction. With guaiacol as substrate it was observed that at 50° C. (122° F.), the maximum activity was reached much earlier than the usual 45 minute interval. The maximum activity with guaiacol as substrate was obtained at 30° C. (86° F.), with o-phenylenediamine as substrate at 40° C. to 60° C. (104° F. to 140° F.), and with pyrogallol as substrate at 49° C. to 50° C. (120° F. to 122° F.). With both o-phenylenediamine and pyrogallol as substrates the activity became totally extinct at 79° C. (174.2° F.).

[1] The enzyme extract was same for guaiacol and o-penylenediamine as substrates but with pyrogallol as substrate it was five times more concentrated.

Heat Inactivation of Peroxidase

Overholser and Cruess *(10)* dipped thin slices of apple in water at different temperatures for five minutes and tested the slices for peroxidase activity. They reported negative tests up to a period of 48 hours after treatment at 100° C. (212° F.). It is recognized that peroxidase from some sources after apparent inactivation by heat is regenerated upon cooling. Thus, Schwimmer *(12)* reported that regeneration of peroxidase occurred in turnip juice.

The following experiments were designed to find the extent and nature of heat inactivation of apple peroxidase as well as reactivation if any, after cooling. The heat inactivation and reactivation were studied at three temperatures, namely 60° C. (140° F.), 70° C. (158° F.) and 80° C. (176° F.). Two ml. of enzyme extract were transferred to thermal death time tubes as descriibed by Kaplan, Esselen and Fellers *(6)* and the tubes sealed (the same enzyme extract was used with all the substrates and temperatures, except with pyrogallol as substrate where the enzyme extract was five times more concentrated). The tubes of duplicate samples were heated in a constant temperature oil bath for varying lengths of time at the three different temperatures mentioned above. At the end of the heating period, the tubes were quickly immersed in ice water and vigorously agitated to insure proper cooling. Immediately after cooling the activity in 1 ml. of the heated extract was determined in duplicate with the three substrates. The average activity is reported. The activity was also determined in a similar manner after 20 hours of incubation at 25° C. (77° F.). The results are presented in Table 6. The activity was regenerated after 20 hours of incubation in all the cases, when the samples were heated at 80° C. (176° F.). At lower temperatures, though there was some regeneration of activity in a few cases, the reactivation was not consistent. The original activity is referred to as 100 percent activity. In no case did the activity return after complete inactivation. This is in agreement with the findings of Kaplan, Esselen and Fellers *(6)* who did not observe any regeneration of activity with peroxi-

TABLE 6

Heat Inactivation of Peroxidase

Temperature	Time of exposure in mins.	Percent activity of Guaiacol-peroxidase		Percent activity of o-phenylenediamine-peroxidase		Percent activity of Pyrogallol-peroxidase	
		Immediately after	After 20 hours	Immediately after	After 20 hours	Immediately after	After 20 hours
60° C.	0	100	100	100	100	100	100
	1	100	100	100	100	100	100
	2	100	100	97.1	100	97.2	93.5
	5	100	100	97.1	100	95.3	86
	10	94.7	100	91.7	100	93.7	77
	20	85.9	94.7	85.8	97.1	86	72.9
70° C.	1	100	100	100	100	97.2	97.2
	2	100	97.2	98.3	100	97.2	95.3
	5	85.9	88.4	80.4	97.1	80.4	77
	10	72.4	65	65	83.3	51.4	43
	15	42.8	47.8	44.6	67.9	37.4	35.5
80° C.	1	94.7	100	91.7	100	95.3	97.2
	2	76.6	90	78.3	91.7	86	72.9
	3	24	24	25	80.8	28	43
	4	15.2	36.6	19.6	52.1	19.6	32.7
	5	6.7	17.4	16.7	30.8	9.4	10.2
	7.5	0	0	10.8	27.1	0	0
	10	0	0	0	0	0	0

dase of tomatoes, pears, peaches and salt-stock pickles 20 hours after complete inactivation. The fact that, whereas partial heat inactivation may result in higher activity after reactivation, total inactivation completely destroys the enzyme, is specially significant in fruit processing.

Summary

Methods of measurement of peroxidase activity with guaiacol and pyrogallol as substrates are given. A new method for the measurement of peroxidase activity with o-phenylenediamine as substrate is presented. This method with o-phenylenediamine as substrate was the most sensitive to colorimetric measurements.

The influence of pH, time, and temperature on the peroxidase activity of apple tissue was determined with the three substrates.

The inhibition characteristics of apple peroxidase with hydrogen peroxide, sulfur dioxide, ascorbic acid, sodium chloride, dextrose, sucrose, thiourea, allylthio urea and glutathione were investigated and it was found that there were differences in activity with the three substrates.

The behavior of what is commonly known as the peroxidase of apples, was not the same with the three substrates studied. Though differences in substrates for peroxidase were noted in both pyrogallol and o-phenylenediamine, guaiacol seems to deviate more from both of them. Such a behavior may be explained by: (1) the existence of more than one peroxidase, each acting on a different substrate and (2) the existence of a single peroxidase acting differently with different substrates. The latter explanation seems most logical. However, it is apparent that the peroxidase activity depends upon peroxidase, peroxide and the substrate and is not independent of the type of substrate. In the light of these observations any conclusions based on the study of peroxidase activity on any one substrate would be premature.

REFERENCES

1. Balls, A. K., and Hale, W. S. Peroxidase in the darkening of apples. *Ind. Eng. Chem.*, **27**, 335 (1935).
2. Cruess, W. V., and Fong, W. Y. The effect of sulfur dioxide on the oxidation of fruits. *Fruit Products J.*, **8**, 21 (1929).
3. Drain, B. D. Oxidase activity in variety of apples. *Proc. Am. Soc. Hort. Sci.*, **20**, 25 (1923).
4. Hussein, A. A., and Cruess, W. V. Properties of the oxidizing enzymes of certain vinifera grapes. *Food Research*, **5**, 637 (1940).
5. Joslyn, M. A. Enzyme activity-index of quality in frozen vegetables. *Food Ind.*, **18**, 1204 (1946).
6. Kaplan, A. M., Esselen, W. B., Jr., and Fellers, C. R. Thermal resistance of enzymes in acid foods. *Ind. Eng. Chem.*, **41**, 2017 (1949).
7. Onslow, M. W. Oxidizing enzymes. I. *Biochem. J.*, **13**, 1 (1919).
8. Onslow, M. W. Oxidizing enzymes. II. The nature of the enzymes associated with certain direct oxidizing systems in plants. *Biochem J.*, **14**, 535 (1920).
9. Onslow, M. W. Oxidizing enzymes. III. *ibid.*, **14**, 541 (1920).
10. Overholser, E. L., and Cruess, W. V. A study of the darkening of apple tissue. Calif. Agr. Expt. Sta., *Tech. Paper* No. **7** (1923).
11. Ponting, J. D., and Joslyn, M. A. Ascorbic acid oxidation and browning in apple tissue extracts. *Arch. Biochem.*, **19**, 47 (1948).
12. Schwimmer, S. Regeneration of heat inactivated peroxidase. *J. Biol. Chem.*, **154**, 487 (1944).
13. Sumner, J. B., and Gjessing, E. C. A method for the determination of peroxidase activity. *Arch. Biochem.*, **2**, 291 (1943).
14. Wallerstein, J. S., Hale, M. G., and Alba, R. T. Oxidizing enzymes in brewing materials: IV. *Wallerstein Laboratories Communications II*, **221** (1948).

Industrial and Legal Viewpoints

Why Food Industry Sanitarians Must Perforce Train Pest Control Operators[a]

(Received for publication, July 25, 1949)

The control of insects and rodents is one of the serious sanitation problems of the food industry. Commercial Pest Control Operators solicit control contracts. While some are well-qualified and do an excellent job at nominal cost, many do not do an adequate job and some actually do more harm than good by carelessness with toxic materials. When competent Commercial Pest Control Operators cannot be secured, plants have no choice but to train their own employees in order to effect dependable control.

The title of this article intentionally leaves the impression that it is a necessity for food industry sanitarians to train pest control employees. At the same time it should be borne in mind that while this endeavor does appear necessary, it is not the desire of any clear-thinking sanitarian to harness himself with such responsibility and additional work. Rather it is his wish to engage the services of a competent commercial pest control operator. However, where are competent pest control operators (P.C.O.'s) to be found?

Dr. E. L. Holmes, Director, Department of Sanitation, American Institute of Baking, published an article in May, 1948, in which, among other pertinent facts, he stated that companies of the baking industry were turning to the recently born commercial sanitation counselors for aid in solving their pest control problems.

Likewise, our Association through its sanitation department has gone a step further in some instances by actually training company-employed workmen to handle some of the specific pest problems that may exist. For that matter, many food plants have successfully and safely supplemented their plant-proofing, and other preventive measures, by fumigants for insect and rodent extermination applied by plant workmen trained for this job.

To return to our title; why are sanitation departments harassed when commercial pest control operators are legitimately seeking this specialized type of business? The answer is very simple and has already been explained by many observing people. In order to reemphasize the reasons, let us say in a straightforward manner that the need for industry-trained pest control operators exists because capable, honest, efficient and safe commercial pest control operators appear to be the exception, not the rule. As a single example, of all the pest control firms available in the dried fruit packing areas of California, there is only *one* we can wholeheartedly recommend without any reservations. There is only *one* we know is in fact rendering an efficient and safe service at reasonable expense. This company operates in only one local area. On the other hand, the work of many commercial P. C. O. fieldmen has been consistently so careless and inefficient that our recommendations have been to terminate the P. C. O. contract. *It is the lesser of two evils to have pests than to have a careless or uninformed P. C. O.*

It is not the desire of any food industry sanitarian to train anyone, either commercial or industry-employed, for pest control work, but in view of the present quality of service prevailing, it seems a necessity.

Our efforts to train industry workmen for specific pest control jobs have resulted in successful control but have not thereby provided an inexpensive service. In discussions at the meetings of the Association of Food Industry Sanitarians the consensus has been that a well-informed, conscientious pest control operator can provide a more efficient and inexpensive service than can a company workman. However, such an opinion does little toward controlling pests in any plant when the search for a competent P. C. O. ends in failure. The hazards involved in trying first one P. C. O. after another in search for a good service may result in disastrous consequences when the plant is visited by the Food and Drug Administration inspectors.

Most food industry sanitarians would be happy to serve, in their own and other industries, as boosters and advertising agents for any P. C. O. if they could locate operators in whom their confidence would be justified. In fact this type of "boosting" has been our pleasure in the case of the one excellent firm referred to above.

If food industries are expected to engage commercial P. C. O.'s, who should train their fieldmen? The report of the first National Sanitation Clinic 1948 states: "The Pest Control industry has the responsibility of developing its own societies for education and training and the establishment of standards of service among its own members." Those who have tried to keep abreast of the problems of P. C. O.'s and their endeavors to improve their services know that the National Pest Control Association has advised, and is advising, its membership as to technical recommendations, requirements of decent inter-industry competition, standards of service, etc. A stupendous effort is being made through news letters, meetings and attendance at University guided "short courses." But the point of pressing importance to the food industry customer is *"Are the desired results being obtained?"* He can answer that question by checking the service that his P. C. O. contract is furnishing. This checking is rightfully the job of the food industry sanitarian. The inspections which have been made in the last few years by food industry sanitarians and others have been revealing, to

[a] Presented before the Ninth Annual I. F. T. Convention, San Francisco, Calif., July 14, 1949.

say the least. We have observed many instances of extreme ignorance and misconduct on the part of commercial P. C. O.'s in their work in food plants. Merely a discussion of these inefficient or dangerous occurrences from our own experience might involve all the time allotted for this paper.

We have mentioned the sincere and extensive educational procedures which are being pursued by the National Pest Control Association and yet the offenses recur. Even at the present time we hear of people being poisoned from restaurant drinking glasses that have been sprinkled with sodium fluoride by a P. C. O. fieldman; a child who died from 1080 in solution which was left in a coke bottle (of all containers) in a private home by a P. C. O.; and we see souffle cups, with residues of 1080, sitting about haphazardly in food plants, placed there several days before by a P. C. O.; *ad infinitum*.

Our conclusion then must be that the information and recommendations included in the educational programs directed toward better P. C. O. service are not being assimilated and applied by many in the P. C. O. industry. Undoubtedly the progressive and competent members of the industry do make good use of the N. P. C. A. programs. An educator once said in effect that trainees may be talked to, or talked at, may attend numerous meetings, view hundreds of photos and illustrations, read volumes of printed material, and yet fail to apply the information to their own activities. This may in part be the difficulty. In addition, the National Sanitation Clinic 1948 states that only six of the forty-eight states now require state licenses for P. C. O.'s. Furthermore, only about one-third of all known pest control operators in this country are members of the N. P. C. A., thereby leaving two-thirds of the firms who are not taking advantage of the educational program which is national in scope. In my opinion a food industry should scrutinize a potential P. C. O. service with special care if that P. C. O. is not a cooperating member of the N. P. C. A.

We reemphasize that the modern pest control operator who wishes to properly service a food plant must be a great deal more than an exterminator. What the food industries of today need is *preventive* sanitation. Most P. C. O.'s today seem to regard the term *pest control* as synonymous with control by chemical aids. For that matter, who can blame the P. C. O. for this idea when many entomologists, rodent control authorities, public health organizations, various governmental agencies, insecticide and rodenticide manufacturers and distributors, and even some sanitarians, predominantly recommend chemical aids when discussing pest control. In realty, successful pest control, which the food industries at present seriously need, involves *preventive* sanitation, *with chemical aids as supplementary assistance only!* To become proficient in preventive sanitation is indeed a large order involving, among other qualifications, a great deal of technical knowledge and experience, salesmanship and organizing ability. These qualities typify the kind of P. C. O. fieldmen that food industries need but seldom find. In fact it is difficult to find fieldmen who have all, or even one, of these qualifications. We speak of the fieldmen because in the final analysis they are the most important members of a P. C. O. organization from the customer's viewpoint. When the food industries realize that P. C. O.'s with these qualifications are almost a rarity, they search for other mediums of assistance such as industry sanitarians and commercial sanitation counselors. Cencerning this last named group there seem to be some who are P. C. O.'s with a new name, while others offer advice or make recommendations only. This leaves the P. C. O. in his original position in regard to his relations with the food industries, namely, he can serve merely as an exterminator of pests which, as we suggested before, is inadequate. It also seems probable that the competing commercial sanitation counselors may well be plagued with the same difficult problems as are commercial pest control operators.

Lest we seem over-prejudiced in our criticism of pest control operators, mention should be made of at least a few of the very difficult barriers that are placed in the way of a good pest control operator in his bidding for contracts and performance of proper service: (1) Lack in some degree of technical knowledge and other qualifications aforementioned; (2) unethical competition with members of his own profession; (3) training and controlling the everyday actions of his own field representatives; (4) confusion that exists as the result of governmental agency attitude and action relative to toxic chemicals; and, (5) frequent resistance of the individual food manufacturer when offered a competent pest control program. This last obstacle may be the most important factor.

The type of P. C. O. service that food industries need has been mentioned, but how often does food plant management *know* it needs this high class service and is *willing to pay* accordingly? Too often food plant management will contract a P. C. O. service, pay the charges (many times a ridiculously low figure) and then lapse into a sense of false security. If the P. C. O. approaches the plant management and requests cooperation in the matter of improved clean-up procedures, physical pest resistance of the plant, keeping materials and equipment accessible for inspection and control, removal of permanent or temporary harborages, etc., he is often confronted with the frank statement, "I'm paying you so much per month to keep my plant free of pests, and if you can't do it, one of your competitors says he can—Good Day!" Here is where the P. C. O.'s technical knowledge, personality and salesmanship are taxed to the extreme. Here also is another place for the industry sanitarian to come to the aid of a good P. C. O. Or the competent operator may hear this, "I have read that a new poison called 1090 or 666 or 534, or something like that, is a simple, inexpensive and perfect answer to all the rodent problems. The stuff even attracts the rats down from the rafters and after taking a lethal dose they run outside the plant and die in their nests. Furthermore, your competitor uses this new poison very successfully and has been after me to take over my pest control at less cost than you charge me." This is another case where the plant operator is the one in need of some education and it must be done in a very tactful manner or the com-

petitor takes over. The *capable* P. C. O. can do it, and a *capable* sanitarian can be of great help.

The whole problem, as we see it, is comprised of two main factors: (1) Will the Pest Control industry make available a high type of service to the food industries, or will it direct its attention to other business which is unaware of what constitutes proper pest control service? Time will tell. Some pest control operators have told us that they are not interested in food industry contracts where a quality control man or sanitarian is apt to check their work. There are plenty of "greener pastures!"; (2) Will food plant management realize the quality service they really need, be willing to pay the legitimate expense, and cooperate in the handling of general sanitation and physical plant deficiencies over which a P. C. O. has no control? Section 402(a)(4), Chapter IV of the Federal Food, Drug and Cosmetic Act of 1938 is a powerful stimulus in this direction.

Because of their interrelated roles, food industry sanitarians and pest control operators should by all means be cooperative and offer mutual aid. Neither group should find it necessary to train the other. The P. C. O. must be willing and able to furnish efficient and safe service at reasonable cost, and the sanitarian must be willing and able to properly advise his food industry concerning its active part in a successful pest control program.

It is our thought that results from employment of a competent commercial exterminator would be greatly improved if the arrangement involved a two-party commitment, the (P. C. O.) employee to perform exterminating services and make recommendations for preventive measures, and the (food industry) employer to act on such recommendations.

Food industry sanitarians are looking forward to the day when they can, without hesitation, recommend commercial pest control operators whom they are confident will understand (a) the problems involved, (b) the degree of pest control which is needed, and (c) who have the integrity and know-how to operate properly. Until this is possible, food industry sanitarians and others feel impelled to advise their employers that it may be necessary to develop their own pest control to protect products and meet the requirements of law and of the consuming public.

DONALD H. LITTLE
Director, Department of Sanitation
Dried Fruit Association of California
1 Drumm, San Francisco, California

The Freezing Preservation of Turkey Meat Steaks[a]

A. A. KLOSE, H. L. HANSON, AND HANS LINEWEAVER
Western Regional Research Laboratory,[b] Albany, Calif.

(Received for publication, September 13, 1949)

Two methods of preparing turkey steaks, with their respective yields, are described. The frozen storage stability of the two types of steaks has been determined by subjective organoleptic tests and by objective chemical tests. Variables which have been studied are temperature of storage, packaging materials, added fat, and repeated freezing and thawing.

The turkey steak is a relatively new product but the idea behind it, to furnish to the consumer an individual-sized piece of meat, is as old as the retail meat business. Interest in the development of marketable units of turkey smaller than the holiday 15- to 25-lb. bird was stimulated by a temporary surplus of turkeys which developed shortly after the end of the last war. Marketing turkeys as halves, quarters, and parts has been tried in a limited way *(1)*. Oregon State College, in cooperation with the Bureau of Agricultural Economics, conducted a consumer survey in 1948 on the marketing of cut-up parts in retail stores. Fischer and DeLoach *(4)* of Oregon State College concluded from this study that a demand for cut-up turkey existed and could be increased by education of the consumer, establishment of a sound merchandising program including close cooperation from the retailer, and improvement of the product through proper freezing and packaging.

Turkey steaks have been prepared and sold in various parts of the country during the past few years *(2, 3)*. For the most part, the operations have been on a small scale, such as one or two local restaurants or retail shops. In Texas, under the stimulation of an Agricultural Extension Service marketing specialist, F. Z. Beanblossom, large amounts of turkey meat have been sold in this form, by a coordinated program involving the processor, wholesaler, retailer, and consuming public.

There are several ways of processing turkeys into steaks. For most efficient utilization of the whole carcass, including the bones, the frozen eviscerated carcass can be cut crosswise into 5/8-inch steaks with a power meat saw. This method will provide about 20 crosscut steaks from a 22-lb. carcass. The 10th and 20th steaks, counting from the neck are shown in Figure 1. Yields of cooked meat from steaks from the different regions of the carcass are presented in Table 1. If a bone-free steak is preferred, the meat can be cut from the bones and formed into 4-oz. steaks by means of a steak machine of the type used to make cube steaks in retail butcher shops. It is a rapid and simple operation to remove the meat from the breast and thigh, and an

[a] Presented before the Ninth Annual I. F. T. Convention, San Francisco, Calif., July 12, 1949.

[b] Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, U. S. Department of Agriculture.

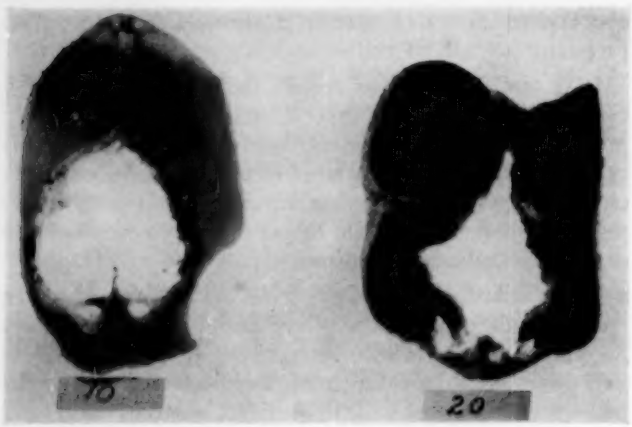


FIG. 1. Tenth (left) and twentieth (right) crosscut turkey steaks, counting from neck.

TABLE 1

Yields of Cooked Edible Meat in Crosscut Turkey Steaks

Steak No.	Uncooked Weight (grams)	Yield of Cooked Meat as % of Uncooked Weight		
		Light	Dark	Total
2	174	35	0	35
4	305	35	1	36
6	426	41	1	42
8	435	42	0	42
10	322	50	0	50
12	178	31	5	36
14	295	21	24	45
16	312	7	28	35
18	337	3	36	39
20	328	0	48	48

increasingly difficult task to obtain tendon-free meat from the drumstick and wing. Hence, it may be more efficient to market the drumsticks and wings as such. A 22-lb. eviscerated carcass will yield about 6.5 lbs. of breast meat and 2.5 lbs. of thigh meat. Figure 2 illustrates the yields of deboned steaks and parts from a turkey carcass.

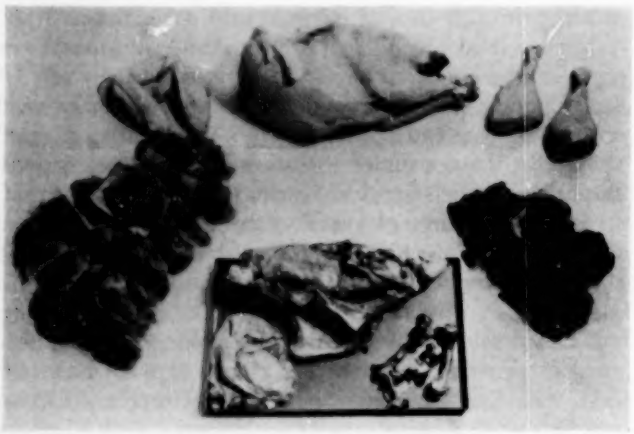


FIG. 2. A 20-lb. eviscerated tom turkey (top center) and its breakdown into wings, 2 lbs.; drumsticks, 2.5 lbs.; light steaks, 6 lbs.; dark steaks, 2.5 lbs.; carcass, 4.5 lbs.; and skin and depot fat, 2.5 lbs.

From the standpoint of efficiency of handling, it would be desirable to be able to slaughter, eviscerate, process into steaks, and freeze in one continuous operation. The large exposed cut surface in the steaks naturally raises the question of how long a storage life can be expected. Experiments carried out at the Western Regional Research Laboratory during the past year and a half have provided some information on the frozen storage stability of these two types of steaks. Included in the present report are five storage studies involving the following variables: (a) temperature of storage for crosscut steaks, (b) temperture of storage for deboned steaks, (c) packaging materials for the crosscut steak, (d) fat added to the deboned steaks, (e) repeated freezing and thawing on the deboned steaks.

Experimental

Effect of storage temperature on crosscut steaks: Crosscut steaks were stored in sealed MSAT cellophane bags at three experimental temperatures: —10°, 0°, and +10° F. Each steak was sawed in two, one-half being stored at the experimental temperature and the other half held at —30° F. as a control. After periods of 3, 6, and 12 months the steaks were defrosted, dredged with flour, and fried for 15 minutes. The steaks were covered for the last 10 minutes' cooking time. The meat and the layer of fat under the skin were evaluated for flavor by a trained taste panel. A flavor score as reported here represents the average of scores by about 8 panel members on approximately 8 steaks. The score of 10 was assigned to no off-flavor and 1 to maximum off-flavor. In most cases the off-flavor can be described as one of fat rancidity. From the panel scores, the relative effects of variations in treatment can be evaluated, and conservative estimates of storage life can be obtained from the times necessary to bring about detectable differences between experimental and control samples.

The uncooked fat from the skin and from the meat was analyzed for peroxide content by a slight modification of Wheeler's iodimetric method *(6)* and for Kreis value by the method of Pool and Prater *(5)*. Skin fat was extracted directly with chloroform and anhydrous sodium sulfate in a blender while the muscle tissue was dried *in vacuo* from the frozen state before extraction. Peroxide value and Kreis values were well correlated with each other, and, with a few exceptions, were well correlated with the development of off-flavor.

Storage of crosscut steaks for as little as 3 months at 0° or +10° F. resulted in slight but significantly greater meat off-flavor than the —30° F. controls. At —10° F., 6 months were required to produce any significant off-flavor, compared to the control. In general, steaks held at +10° F. for 3 months, 0° F. for 6 months, and —10° F. for 12 months had equivalent flavor scores. Figure 3 indicates the relative deterioration in flavor at four temperatures for the light meat. The same trends were found for the dark meat steaks, but with the panel consistently grading the dark steaks lower than the light. Peroxide tests revealed significant differences between each of the three experimental temperatures and —30° F. control for the meat fat at 3 months and thereafter, but for the skin fat only after 6 months of storage.

Effect of storage temperature on deboned steaks: Essentially the same evaluation procedures were used in this and subsequent experiments as were described above. Light and dark meat steaks from 12 turkeys

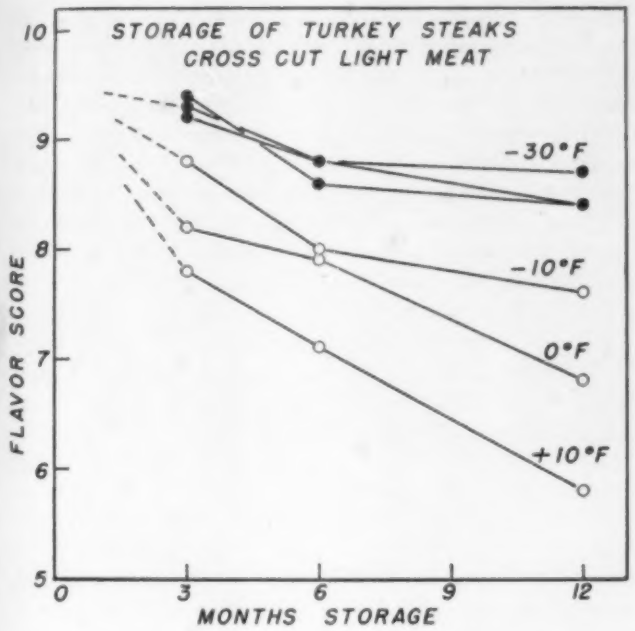


FIG. 3

were stored at —30, 0, and +10° F. All differences between the three temperatures for the dark meat steaks were highly significant at 3 months and thereafter. With the exception of 0° vs. +10° at 3 months, all differences between temperatures for the light steaks were significant. The dark meat developed off-flavor at a more rapid rate than the light meat. This may well be related to the greater fat content of the dark meat, and will be discussed in connection with a more direct experimental test of this point described below. Both flavor scores and peroxide contents of dark meat steaks have been plotted against storage times in Figure 4. By a suitable adjustment of the zero point and size of the scales, a reasonably good correspondence is obtained between the solid curves denoting flavor scores and the dotted curves representitng the logarithms of the

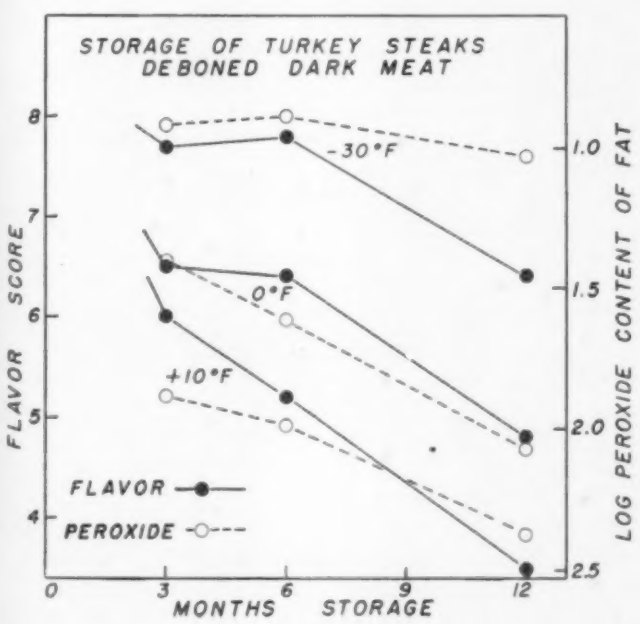


FIG. 4

peroxide content. The essential linearity of the curves of log peroxide content vs. time is in harmony with the generally accepted autocatalytic nature of the fat deterioration reaction. A distinct color difference was noted between —30° F. and +10° F. steaks at 6 and 12 months' storage. The —30° F. stored steaks maintained a fresh pink appearance, while those stored at the higher tempertures became dull, yellow-gray.

Evaluation of packaging methods: Satisfactory packaging is, of course, almost as important as low temperature in guaranteeing a satisfactory storage life for this type of product. Cross-cut steaks were stored in four packaging materials—MSAT cellophane, polyethylene, aluminum foil, and parchment paper. In order to have a satisfactory positive control, each frozen eviscerated turkey was sawed in half down the middle. One half was then cut crosswise into steaks, packaged in the various materials, and stored at 0° F. The other, or control half, was stored in a polyethylene bag at 0° F., and cut into steaks at the end of the storage period. Meat stored in the piece and cut at the time of evaluation (3, 6, and 12 months) was in all cases superior to the packaged steaks, in respect to the retention of fresh flavor and fresh pink color. Differences for the skin fat and dark meat were more consistently significant than for the light meat. Essentially equivalent protection was obtained with aluminum foil, polyethylene, and cellophane, while parchment gave definitely lower scores. The extent of dehydration in deboned steaks, which would be expected to be more susceptible than the crosscut, was measured in sealed cellophane and wax paper bags for 3 months and 6 months of storage at 0° F. Moisture losses, as percentage of the total original weight, are given in Table 2. The wax paper permitted much greater loss than the cellophane, as was to be expected.

TABLE 2

Moisture Losses in Deboned Steaks at 0° F. % of Original Weight.

	Wax Paper	Cellophane
Light Meat		
3-month storage	3.2	0.9
6-month storage	8.8	1.9
Dark Meat		
3-month storage	5.1	0.8
6-month storage	11.9	1.4

Effect of the addition of fat to deboned steaks: It would be desirable to include the skin fat and other fatty tissues in the deboned steaks, if only to increase the efficiency of utilization of the whole carcass. Rendered turkey skin fat and neck tissue fat were incorporated in deboned steaks and their effect on the frozen storage stability was measured. About 5 percent of rendered fat or 10 percent of tissue fat was added to the light and dark meat steaks and intimately mixed by 2 to 3 passages through a steak machine. Immediate evaluation of light meat steaks prepared with rendered fat showed no improvement in flavor or juiciness due to the added fat. The average flavor scores after 3½ months' and 8 months' storage at 0° F. are presented in Table 3. Rendered fat decreased the stability significantly, and tissue fat even more so. All differences between control, rendered fat, and tissue fat steaks were

TABLE 3

Effect of Fat Added to Deboned Steaks on Storage Stability at 0° F.

Additive	Flavor Score			
	Light Meat		Dark Meat	
	3½ months	8 months	3½ months	8 months
None	7.7	7.6	7.1	5.6
Rendered fat	7.2	5.6	6.7	4.5
Tissue fat	5.9	4.7	....	....

significant, except for the difference between control and rendered fat at 3½ months. There were no significant differences in juiciness between groups. Although all groups showed appreciable rancidity by the peroxide test (20-30 meq./kg.), there were no significant differences between controls and steaks with added fat after 3½ months. After one years' storage the peroxide contents showed the same trends as we have mentioned for the flavor scores.

Effect of thawing and refreezing: Conditions roughly simulating what might happen in frozen food display cases, but accentuated to bring out any slight effects, were imposed on deboned steaks before storage in one case, and after storage in another. The steaks were thawed at room temperature, refrozen at —30° F., and stored at 0° F.; this cycle was repeated five times over a five-day period. When light-meat steaks were stored for four months, there were no significant differences between flavor scores of controls and of either those thawed and refrozen repeatedly before storage or those treated in the same way after storage. For the dark steaks at 4 months, the control was significantly better than either of the thawed groups. After 8 months all scores were low and there were no significant differences between treatment groups. Bacterial (aerobic) counts [e] were made on a limited number of these steaks, and found to be quite low. At 4 months the counts were in the following increasing order: control, thawed repeatedly before storage, and thawed repeatedly after storage; but practically all steaks had counts under 7,000 per gram. At 8 months no counts were above 3,000 per gram, and those thawed before storage had higher counts than the other two groups. Determination of the peroxide contents of the 8-month samples indicated at least twice as much in the thawed samples as in the control, with no significant differences between the two methods of thawing.

Discussion

People who have eaten turkey steaks are generally of the opinion that it is an acceptable meat course, but they usually object to the fact that the steaks do not taste like roast turkey. Possible explanations for this difference include the different times of cooking, and the seasoning which is conventionally incorporated into the roast bird. It should be pointed out to the prospective consumer that he should not expect a turkey steak to taste exactly like roast turkey any more than he would expect a beef steak or a lamb chop to taste exactly like a roast of the same kind of meat. The turkey steak represents a product which potentially can provide an additional tasty item for the American menu and in so doing can increase the year-round consumption of turkey meat.

[e] We are indebted to R. P. Straka for these bacterial counts.

Summary

Crosscut turkey steaks packaged in cellophane and held at +10° F. or 0° F. showed flavor deterioration in 3 months when compared with controls held at —30° F. Steaks held at —10° F. did not show significant differences from the controls until 6 months of storage. Dark meat deteriorated more rapidly than light meat; hence dark meat steaks should be prepared and packaged separately. The addition of turkey fat to the deboned meat accelerated the development of off flavors. A greater deteriorative effect was obtained with whole tissue fat than with rendered fat. Evaluation of steaks to which freshly rendered turkey fat had been added just before cooking showed no beneficial effect of the fat on flavor or juiciness. Essentially equal protection was obtained from cellophane, polyethylene, or aluminum foil, while the best retention of quality was obtained by storing the meat in the form of the packaged half bird, and cutting into steaks just before evaluation. Considerable amounts of thawing and refreezing had little effect on quality of stored steaks. In most cases, significant decreases in flavor were correlated with significant increases in peroxide content of the fat.

Acknowledgments

We are indebted to Catherine S. LaDu for technical assistance in flavor evaluation, and to Iva S. Streeter for chemical analyses of the fat.

LITERATURE CITED

1. Anon. Distributors ready for frozen turkeys. *Frosted Food Field*, **5**, 4 (Nov., 1947).
2. Anon. New way of marketing turkeys may open new markets for them. *U. S. Egg and Poultry Mag.*, **53**, 8 (May, 1947).
3. Anon. Turkey steaks for year-round sales. *Food Freezing*, **3**, 32 (Dec., 1947).
4. Fischer, C. M., and DeLoach, D. B. Consumer response to the marketing of cut-up turkey. Oreg. Agric. Expt. Sta. *Bull.*, **457** (Aug., 1948).
5. Pool, M. F., and Prater, A. N. A modified Kreis test suitable for photocolorimetry. *Oil and Soap*, **22**, 215 (1945).
6. Wheeler, D. H. Peroxide formation as a measure for autoxidative deterioration. *Oil and Soap*, **9**, 89 (1932).